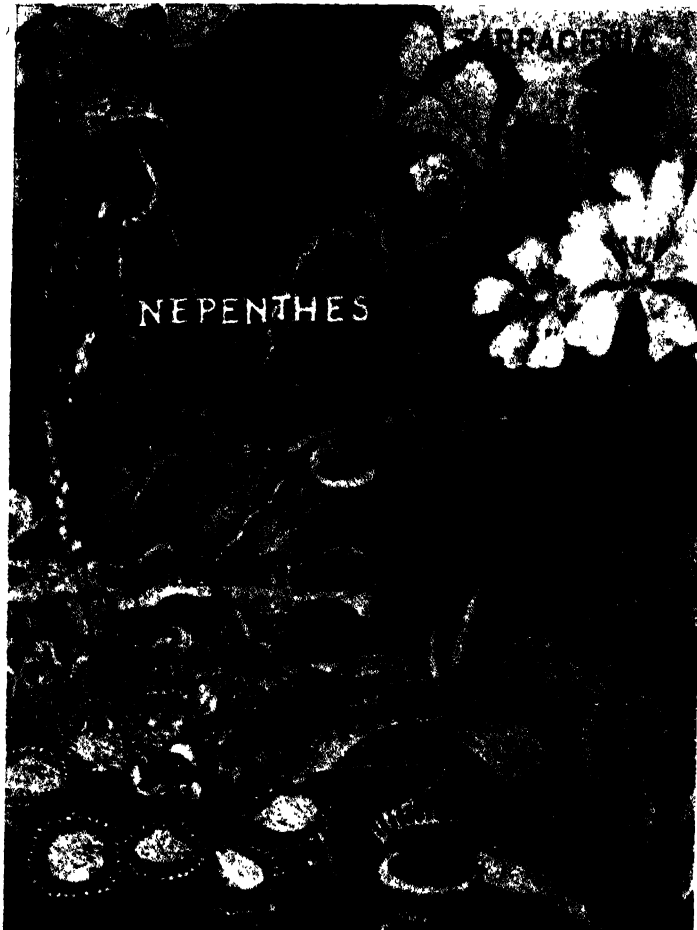
ELEMENTARY BOTANY



INSECTIVOROUS PLANTS

SEE PAGE 302

Elementary Botany
For Indian Schools & Colleges

BY

H. N. MITRA, M.A., B.L.

Professor of Botany, Bangabasi College, Calcutta
Member, British Ecological Society; Examiner
in Botany, Calcutta University: Author
of Structural Botany Etc.

FIFTH EDITION

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PREFACE TO THE FIRST EDITION.

Some years ago I was asked by a number of friends to write a book on Indian Botany for the use of junior students of our Universities. This has been a long felt want for it is extremely difficult for a beginner to study Botany with the help of English text books which deal with European plants and are surely not written from the view-point of the Indian student. To meet this want my "Structural Botany" was published some two years back and notwithstanding many of its defects, especially its elaborateness, the book found ready acceptance at the hands of the University, teachers and students. This success must, I think, be ascribed more to the Indian tone of the book than to any intrinsic merit of its own, and has encouraged me to bring out the present volume.

In this volume my aim has been to present the elementary portions of the science required to be studied by the junior students of our Universities as simply and as lucidly as possible. Throughout I have used vernacular names along with their English or Latin equivalents and illustrated the book as copiously as possible with commonly occurring Indian plants and their structure. This I hope will greatly facilitate the work of our students and enable them to acquire a general knowledge of Botany with special reference to the Indian flora. In order that full advantage may be taken of the vernacular names I have added an appendix which sets forth the synonymous names of plants current in the different provinces of India.

Great difficulty was experienced in giving original micro-drawings for Part II of this volume. These drawings as well as many other original ones in the other parts of

the book have been executed faithfully by my brother, Mr. Nripendra Nath Mitra, who has also helped me unremittingly in going over the proof sheets and in drawing up the index.

I cannot express how greatly I am indebted to Prof. S. C. Mahalanobis, B.Sc., F.R.S.E., for his kindness in going over the whole of my earlier work, Structural Botany, and preparing a full list of corrections and for his numerous valuable suggestions. I have taken full advantage of these corrections and suggestions in the present volume, but I am wholly responsible for the errors of fact that may have escaped scrutiny and for the few innovations that I have purposely introduced in the hope of securing consistency. Nor can I close this note without expressing my grateful acknowledgments to Principal G. C. Bose and to many of my friends for their numerous hints and suggestions, and more than anything else, for the encouragement they have accorded me in a field where encouragement is badly needed.

BANGABASI COLLEGE,
Calcutta, *August 1915.*

H. N. MITRA

PREFACE TO THE SECOND EDITION.

In this edition extensive changes have been introduced. The whole of the first and the second parts of the book dealing with Morphology have been entirely rewritten. The other parts have also been revised and rewritten at some places, especially with a view to removing matters not required to be learnt by junior students, and replacing others which suffered from an obscurity of language. A large number of new illustrations have also been added, but the original idea of giving analytical pictures of every common plant has been found very difficult to carry out owing to war-conditions. A summary and a set of questions have been added after the chapters wherever necessary; it is hoped they will be of substantial help to students, especially for rapid revision.

BANGABASI COLLEGE
Calcutta, *January 1918.*

H. N. MITRA.

PREFACE TO THE THIRD & FOURTH EDITION.

In this edition a few more wood-cuts have been added. Owing to pre-occupation the author has not been able to revise the book thoroughly, but still certain improvements, such as the insertion of small paragraphs on economic plants under the Natural orders, have been made and a glossary of Botanical terms has been added at the end. A more thorough list of the vernacular names of plants current in the different provinces has been given, and this, it is hoped, will greatly help students outside Bengal who now so largely depend upon this book.

ANNUAL REGISTER OFFICE
Sibpur, *April 1921.*

PUBLISHER.

PREFACE TO THE FIFTH EDITION.

This edition is being published under the shadow of the greatest misfortune that could befall us. Our editor has been prematurely summoned to his Heavenly Home on the 29th September last. We are issuing this edition as an exact reprint of the previous one (with, of course, such addition in Natural orders which have been lately introduced into the Syllabus). We have spared no pains to look to the printing and get-up, and with the blessings of the illustrious deceased we hope to have placed before our readers the very likeness of the late Prof. Mitra's handiwork.

We do hope and trust that our readers would encourage us to continue this publication and thus keep alive the work of the great scholar who, be it remembered, was the first to bring before the Indian Students of Botany a real complete text book on the subject, and very kindly favour us with their suggestions for improvement for the next improved edition which we would take in hand in the near future, and in which we have been voluntarily offered the collaboration of distinguished scholars in Botany amongst Prof. Mitra's friends and students. We will also introduce a large number of additional tri-coloured plates and blocks in the next edition.

ANNUAL REGISTER OFFICE
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PUBLISHER.

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INTRODUCTION.

Botany is the science of the vegetable kingdom. It is divided into several parts or departments each dealing with a particular side of the soience of plants. These are.—

1. **Morphology**, which deals with the *form* and *structure* of plants; for instance with the various forms of stems, roots, leaves, and so on. The term means the *science of forms.*

2. **Physiology**, which deals with the *functions* of plants; that is to say, with the work done by the stem, leaf, root, etc. It enquires: How the plant lives, how it feeds, how it multiplies, and so forth.

We all know that the plant takes its food from the soil: but how does it actually feed, and what does the plant feed upon? We know that the plant requires water; but how does it absorb water? We know that the plant requires light, it can not grow in darkness; why does it require light, what is the effect of light or darkness upon plants? How is the life of a plant affected by light, heat, moisture, etc? All such questions involving the *life* of the plant are studied in *physiology.*

3. **Systematic Botany**, which deals with the *classification* of plants. Here we try to find out the similarity between different plants so that they may be formed into groups, the groups in their turn showing near alliances. In this way the whole plant-kingdom may be divided into a number of groups or families of plants. For instance, there are various forms of palms but they all are alike in certain respects and so constitute a close family, namely the Palm family. different altogether from, say, the Cucumber family or the Rose family. A parallel is seen

in the animal kingdom which is easily divided into such families as Birds, Reptiles, Mammals, and so on.

4. **Ecology**, which studies the relation between the form of a plant and its surroundings. Plants which live under different conditions are naturally very different. For instance, water plants are soft and delicate, land plants are harder, plants of dry places are dwarfy and very hard, and so forth. We know that some plants can bear great cold, others can not; some can live in very poor soil, others can only live in a rich soil; some can bear great heat, others remain in shady places and so on. *Ecology* studies how the form and mode of life of plants are adapted to their surroundings.

Fig. 1. Fig. 2. Fig 3.

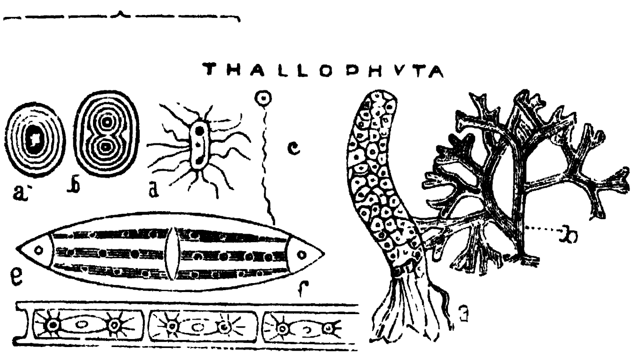


Fig. 1. Simple microscopic Algæ; F, a filamentous Alga.
Fig. 2. A minute plant forming an undifferentiated thallus.
Fig. 3. A minute plant with a branched thallus.

Morphology is divided into (1) *external Morphology*, which deals with the external parts or limbs of plants, such as the stem, root, leaf, etc, and (2) *internal Morphology* which deals with the internal structure of plants—such as their bones and tissues. Just as the animal body is

made up of tissues, such as muscles, veins, nerves, bones and so on, so too the plant-body is made up of tissues. The internal structure of plants or internal morphology is studied under **Plant Anatomy or Histology.**

Kinds of Plants.—Root, stem, leaves, flowers and fruit are of course found in *most* plants, but not in *all*; for instance, they are wanting in the Mushroom which is a plant, for it lives and grows like a plant, though it is very different in form and structure from ordinary green plants. A very similar plant is often found in the form of thick fleshy white plates growing on the bark of trees or on old rotten bamboos. Plants which have no members such as stem, root, leaf, etc., are said to be *undifferentiated*. Their simple memberless plate-like body is called **a thallus**, as opposed to a **cormus** which is a plant-body having distinct members. Thallus plants constitute a class, the lowest class of the plant kingdom, like the worms of the animal kingdom, called **Thallophyta**. Some of the thallophyta are extremely minute (fig. 1), they cannot be seen with the naked eye; they live in water or in moist places. The mushrooms are very big thallophytes; the moulds (chatadhara) formed on rotten vegetables, jellies, chutneys, on old leather or ink are simpler thallophytes. They consist of long white interwoven threads. The green slimy floating masses often found on the water of ponds and marshes are also simpler thallophytes; they consist of interwoven *green* threads. The green thallophytes live in water or moist places; they form the class known as **Algae**. The white thallophytes, like the mushroom and the

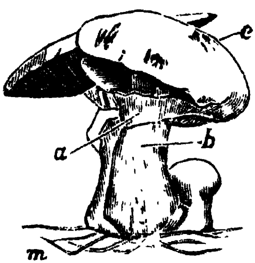


Fig. 4. The Mushroom—a thallophyte.

moulds, live on decaying matters and form the class called **Fungi**.

Fig. 5. Fig. 6. Fig. 7.

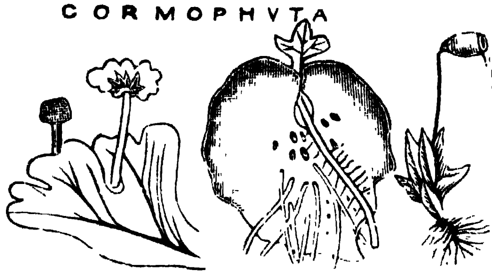


Fig. 5. A Thallus with a small upright shoot or cormus.
Fig. 6. Thallus of Fern with the leafy shoot or cormus.
Fig. 7. The Moss plant—a cormophyte.

Cormophytes have distinct members such as stem, root, leaf, etc. Mosses, (fig. 7) often found on damp walls, are the smallest and simplest of cormophytes. They have very simple leaf and stem and root-like structures but have no flower; so too the Ferns which are bigger plants. Ordinary plants are flowering plants; the ferns (fig. 8) and the mosses are non-flowering plants. The object of the flower is to produce fruit within which are developed the seeds. The seeds are very important for they serve to multiply the plant. Hence flowering plants are also called seed-plants. Flowerless plants such as the ferns, the mosses, the algæ and the fungi, do not produce seeds. But how are they propagated? They produce certain minute dust-like bodies, called **spores**, which are scattered by the wind and thus multiply the plant. Hence flowerless plants are also called **spore plants**. The spores may be easily observed at the back or under-surface of a mature fern-leaf, where they form a thick coating of a brown powder.

Fig. 8. A Fern plant.

Flowering plants form the major portion of the vegetation of the globe. They are divided into three great classes : (1) Pines—trees with small needle-shaped leaves, (2) Dicots—plants with small leaves and often with branches, and (3) Monocots—plants with comparatively large leaves having a sheathing base. For instance Mango, Rose, Banyan, Pea, Java, Jack, are Dicots; the Palms, Grasses, Pineapple, Banana, are Monocots. The former are as a rule much branched, the latter are often unbranched. The distinction between Dicots and Monocots lies in the structure of the seed as will be seen in the next chapter.

The following table gives the main groups of plants.

Flowering Plants or Seed plants—

1. Dicots, E. G., Mango, Rose, Java, etc.
2. Monocots, E. G., Banana, Palms, Grasses, etc.
3. Pines.

Flowerless plants or Spore plants—

Cormophyta, plants with stem and leaves.

4. Ferns.
5. Mosses.

Thallophyta, plants with a thallus.

6. Algae—Green.
7. Fungi—Colourless or white.

CHAPTER I.

GERMINATION.

If a few Pea seeds be laid in water or moist earth it will be noticed in a short time that the seed swells and then its outer coat (called the **testa**) can be easily torn off. Inside the testa lies the kernel of the seed which easily splits up into two halves (figs. 9a, 11c) which are called the **cotyledons** or seed leaves. Between them nestles a very small body in which the rudiments of the stem, leaf, and root can be distinguished. The pointed end of this is the rudiment of the root called the **radicle**; at the other end is the rudiment of a bud called the

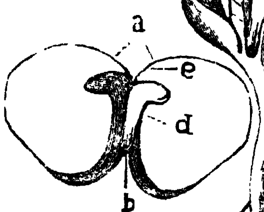


Fig 9. Pea seed—a, cotyledons; d, axis; b, radicle.

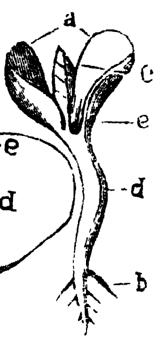


Fig. 10. Bean seedling—a, cotyledon, c, plumule; e, epicotyl; d, hypocotyl; b, root.

Fig. 11. Seed of Bean—c, cotyledons, p, plumule, r, radicle.

plumule (fig. 10). If the seeds are placed in moist loose earth the cotyledons first swell up and break the testa, and the radicle then comes out. It then bends down into the

earth and grows up into the root. The plumule also lengthens in a short time, but it grows straight up into the air and unfolds the first green leaves of the seedling. If we now dig up the seedling we notice that the cotyledons have softened and contracted, and as the stem continues to grow producing leaf after leaf the cotyledons buried in the earth gradually wither and fall off.

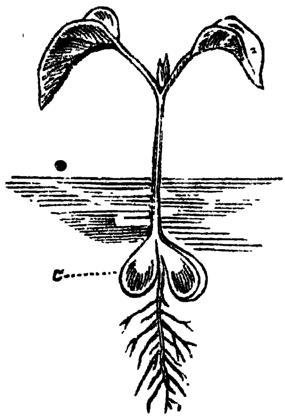
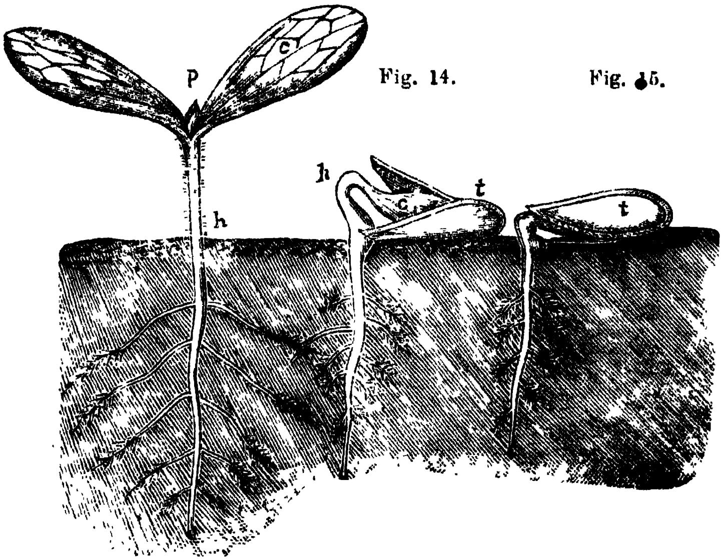


Fig. 12. Seedling of Pea – c, cotyledons.

The seed, then, consists of two parts: (1) the protective seed-coat or testa, and (2) the embryo-plant having cotyledons, plumule and radicle. The cotyledons store a large quantity of food reserved for the nourishment and growth of the embryo. The seed germinates only when it gets water, and also some amount of heat from the soil, for in a cold soil germination can not take place. The cotyledons absorb water, swell up, and push out the plumule and radicle from the split testa; they also soften, so that the reserve food matter which is in a very condensed form becomes gradually softened and soluble in water and so easily digestible. The plumule and the radicle grow at the expense of the food matter stored in the cotyledons, but this is exhausted by the time that the seedling has developed well with roots in the earth and leaves in the air. Now the little plant can live independently, for its root absorbs nutriment from the soil, and the empty cotyledons are of no further use; they dry up and wither away.

Germination of Cucumber.—The seed is flat and rounded at one end and tapering at the other. If we place the seed in moist earth a sticky matter soon forms on

Fig. 13. Fig. 14. Fig. 15.



Figs. 13—15. Germination of Cucumber; fig. 15. seed coat (t) split open and radicle coming out; fig. 14. Same later stage with hypocotyl h, dragging the cotyledons c out of the gaping testa.

Fig. 13. The seedling plant—h, hypocotyl, P, plumule.

the surface and this fixes the seed to the soil. Within a few days the seedling comes out. At first the radicle peeps out from the narrow end of the seed, and the seed-coat is split open by the swelling of the contents of the seed. The radicle bends down and grows straight into the earth. It produces branches and thus fixes the seed to the earth. At this stage the portion of the axis just above the radicle grows strongly, and since the seed is attached at two points,

first by the root and secondly by the sticky seed-coat, the growing axis bends strongly upwards like an arch and splits the seed-coat wider and wider. The gaping seed then liberates the two cotyledons so long imprisoned within the testa, and then the axis bearing the cotyledons, called the *hypocotyledonary axis* or simply the **hypocotyl**, grows straight up into the air. The cotyledons here too are thick and fleshy; but they do not lie buried in the earth as in the Pea; they come out in the air and become green like ordinary leaves. Between them lies the small plumule. A much similar germination is that of the Bean-seed (figs. 10, 11), only here the leaves of the plumule come forward almost before the root has fixed the plant to the soil.

In all these three cases we see that the whole kernel of the seed is the embryo, that there are two cotyledons, hence these plants are said to be *Dicotyledonous* or simply **Dicots**, and that the cotyledons are swollen because they store food matter for the growth of the plumule and the radicle. In Pea cotyledons are very swollen; they have lost all likeness to leaves, they simply act as the store-house of food, and remain always buried in the earth. Such cotyledons are said to be **hypogeal**. In the Bean, Cucumber, Gourd, Melon, Morning glory, Sunflower and many other plants, the cotyledons store food matter no doubt, but they are ultimately pushed into the air by the hypocotyl; they become green and have the appearance of ordinary leaves. Such cotyledons are said to be **epigeal**. The embryo consists of a very short axis; this terminates in the plumule above and the radicle below, while about midway are developed the two cotyledons. The part of the axis which lies below the attachment of the cotyledons is called the **hypocotyl**, the part which lies above it is the **epicotyl**. In Pea it is the epicotyl which elongates; in Bean, Cucumber

and the other cases mentioned, it is the hypocotyl which elongates and pushes the cotyledons and the plumule up above into the air.

The whole kernel of the seed is not always the embryo as in the cases mentioned; nor are the cotyledons always fleshy. In the Castor-oil or Poppy seed the embryo is minute and lies embedded in an oily matter. Examined with a lens after proper dissection the embryo reveals the presence of two small cotyledons, a still smaller plumule, and an almost insignificant radicle; the whole surrounded by an oily matter. When germination begins the cotyledons remain for some time inside the seed, the radicle protrudes as usual and fixes itself to the soil. Then the hypocotyl arches and elongates but instead of dragging the cotyledons out of the split seed-coat, it draws the whole seed up and becomes erect. Gradually the oily matter, which is really the reserve food-matter kept in store for nursing the embryo during germination, is absorbed and then the empty seed-coat is detached like husk and the cotyledons are liberated. Like ordinary green leaves they now appear as thin, flat, green structures which from this time onwards behave exactly like leaves. The food stored in the seed is called **albumen** or **endosperm.**

Thus the seed here consists of .—

1. The seed-coat or *testa.*

2. The *embryo* which is very small and lies embedded in a reserve food called

3. The *albumen.* Seeds with albumen are called albuminous, they have a small embryo; seeds without the albumen (Pea, Bean, Cucumber, etc.) are called exalbuminous, they have a large embryo the major part of which is the cotyledons. Albuminous seeds have their food stored outside the embryo; exalbuminous seeds store their food

inside the embryo in the fleshy cotyledons. All the cereals, Rice, Maize, Oats, and the Grasses and Palms have albuminous seeds. They have a minute embryo and a large albumen.

Germination of Rice.—The Rice grain is really a very small fruit. The two husk protect the real grain, the thin pink-coloured coat of which is made up of the testa or seed-coat and the wall of the fruit. The rough husks serve to attach the grain to the soil so that it may not be washed away by rain. If we remove the husks and examine the pink grain we notice a minute whitish body at one end. This is the embryo (fig. 18a). The rest is albumen which supplies nourishment to the embryo as it grows up into a seedling plant. If we cut the grain into two lengthwise and examine the embryo with a lens, we shall see that the embryo lies in contact with the albumen by means of a short structure (fig. 17s). This is the cotyledon. The free edges of this curl out and enclose the plumule and the radicle in the form of a thin membranous sheath. The part of the cotyledon which connects the embryo to the albumen (fig. 17s) is called the *scutellum*; during germination it pierces the hard albumen, dissolves it and makes it easily assimil-

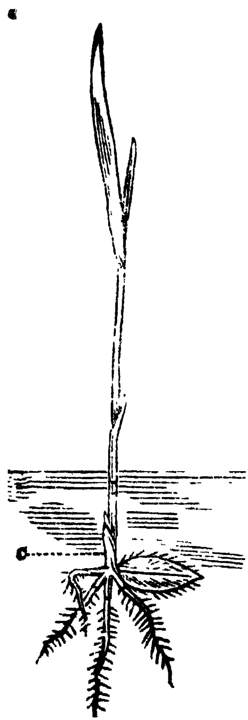


Fig. 16. Seedling of Rice plant; c, the cotyledon.

able. The food thus prepared is then sent to the plumule and the radicle in a dissolved state. First the radicle pierces the sac-like covering of the cotyledon, (fig. 19r), bends down and penetrates into the ground, and develops into the root. The plumule also grows and elongates by

Fig. 17.

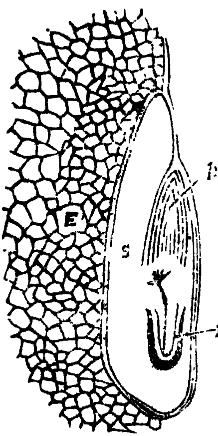


Fig. 18.

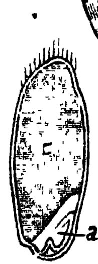


Fig. 19.

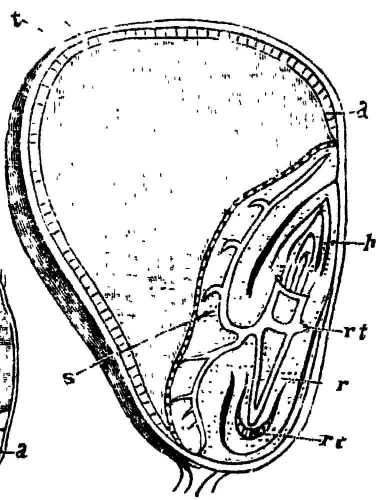


Fig. 17. Longitudinal section of Rice grain magnified to show S, the scutellum ; E, the albumen-tissue ; p, the plumule ; r, the radicle.

Fig. 18. Rice grain slightly enlarged ; a, the embryo ; E, the albumen.

Fig. 19. Wheat grain greatly enlarged ; s, scutellum ; P, t ; the wall of the grain including the testa ; a, the first layer of the albumen ; p, plumule ; rt, the branch root ; r, radicle ; r.c, the root-cap.

piercing the cotyledon-sheath which now remains behind as a thin scale lying at the base of the stem (fig. 16c).

Here we have only one cotyledon, and hence the plant is said to be Monocotyledonous or shortly a Mono-

cot. All the grasses and cereals and bamboos are Monocots. They germinate precisely in the same way as the Rice grain. The grains are all albuminous, have a very small embryo lying by the side of the albumen, and possess but a single cotyledon.

Germination of Cocoa-nut.—This is interesting because of its peculiar cotyledon. The hard shell of the 'nut' is not the testa, it is the inner layer of the fibrous fruit. The shell can be carefully cracked so that the round seed inside comes out unbroken. On the surface of this ball-like seed is a thin brown layer—this is the *testa.* Below this is the hollow, white, tough and cartilage-like substance. This is the albumen. In a young fruit this is a thin soft layer while the cavity is filled with a sweet watery liquid which in the ripe fruit becomes milky and unpalatable. The white tough kernel of the seed is wholly albumen, and the embryo is a minute yellowish body imbedded in it at one of the three 'eyes' of the shell. On germination at first a stout root-like structure comes out of the 'eye'. This is not, however, the root; it is the lower part of the cotyledon rolled up into a tube or sheath round the hypocotyl and its bud (plumule), and also covering the radicle. The upper part of this cotyledon (fig. 20) remains inside the seed in contact with the reserve food which it gradually absorbs. This part of the cotyledon forms a spongy mass filling the cavity of the seed; at this stage there is no

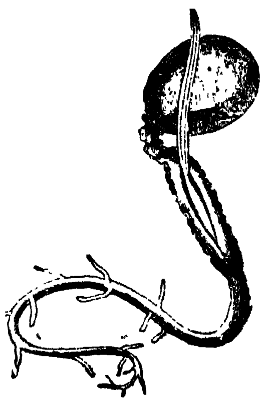


Fig. 20.
Germination of a Palm.

'milk'. The outer part of the cotyledon enclosing the plumule and radicle bends down and is greatly elongated ;

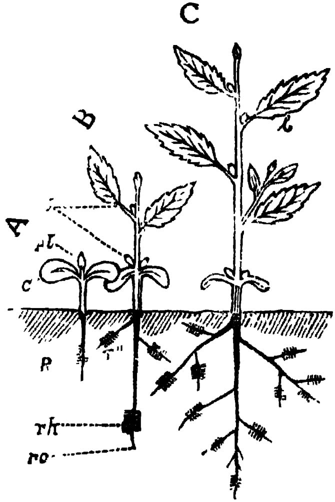


Fig. 21.

Fig. 21. Development of a Dicot. A—R, primary root : Pl, plumule ; C, cotyledons.

B—R, root-cap ; Rh, root hairs ; R'' secondary roots ; l, buds.

C—the fully developed plant.

its central part is swollen and contains the hidden plumule and radicle. Gradually the food matter of the albumen is brought to this part by the stem-like elongated cotyledon after it is rendered soluble and easily assimilable by the spongy part of the cotyledon lying inside the seed. Then the radicle and plumule grow up, elongate, and pierce the cotyledon sheath (fig. 20), the plumule growing upwards into the air and the radicle downwards into the earth. The germination of the Tal (Palmyra Palm) and other Palms is much similar. The spongy cotyledon of Tal (Taler-phonphor) is eaten with relish in the country :

it is full of a sweet juice which the cotyledon prepares from the hard albumen. The Palms are all Monocots; their seeds are all albuminous.

Dicots and Monocots then differ mainly in the number of cotyledons in the seed; Dicots have *two* cotyledons and Monocots only *one*. Another important difference is that

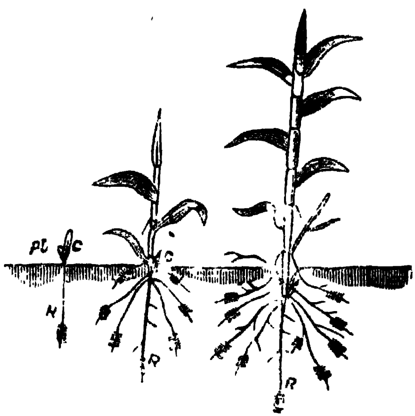


Fig. 22.

Fig. 22. Development of a Monocot. A—R, primary root, pl, plumule, c, cotyledon. B—later stage. C—the fully developed plant with numerous adventitious roots arising from the lower part of the stem

the radicle in the Dicot is prolonged into a root which grows continuously and forms branch-roots (fig. 21); that of the Monocot however is short-lived, it does not grow continuously and forms at the most few branch-roots. The first root of the Monocot soon dies but very early new roots spring from the *lower part of the hypocotyl* and the stem, as shown diagrammatically in fig. 22 (see also next chapter). The following chapters of Morphology deal almost exclusively with Dicots and Monocots and their other differences will appear later on.

SUMMARY.

Germination is the process by which the embryo of a seed develops into a plant. The conditions necessary for germination are: (1) water, (2) heat, and (3) air. Seeds contain very little water and unless these conditions be fulfilled the embyro remains dormant inside the seed. The seed has (1) an outer protective coat or testa, (2) a store of reserve food or albumen for the nourishment of the embryo, and (3) the embryo. In some seeds the embryo is very small and the albumen large—these are called *Albuminous Seeds—e.g.*, all cereals, Palms, Castor oil, etc.; in others the embryo is large with fleshy cotyledons which store food-matter and fill up the whole cavity of the seed, and a separate albumen is not present—these are *Exalbuminous Seeds e.g.*, Pea, Bean, Cucumber, Melon, etc. In germination, first water is absorbed by the seed; it swells, the seed-coat bursts, the swollen embryo is pushed out, and the reserve food of the albumen or of the cotyledons then become gradually converted into easily assimilable matters under the action of water, heat and air. This food then goes to the plumule and radicle to nourish them.

QUESTIONS.

1. Distinguish between Dicots and Monocots. What is the use of the cotyledons?

2. Describe the germination of Cucumber or of any seed.

3. What are albuminous and exalbuminous seeds? Give six examples of each.

4. Examine the following seeds and describe their parts: Pea, Cucumber, Tamarind, Mango, Date, Betel-nut and Wheat.

5. Compare the germinations of the Pea, the Bean, the Cucumber, and the Rice.

CHAPTER II.

THE ROOT.

From the last chapter we learn that the radicle grows up into the root. To study the root we should first examine a few seedlings grown on coarse sand or moist blotting paper. We may also pull up seedlings grown in pots or seed-beds, but then the earth about each seedling must be first carefully loosened so that the tender root is not injured, and the adhering mud washed away in a gentle stream of water. This washing is not an easy task, for the particles of mud (fig. 24) stick to the root with great tenacity.

In a well grown root of a seedling we notice that the tip is smooth and conical, a shape well suited to bore through the soil. At a short distance behind the tip the surface is rather velvety or hairy, being clothed with fine white silky hairs (fig. 23). It is here that the particles of soil adhere so firmly. The hairs are called **root hairs**, while the tip of the root has a brownish cap, called the **root-cap**. Behind the portion of the root clothed with hairs the surface is smooth, and further away root-lets are seen to be growing out (fig. 21). In an old root we can easily distinguish four regions: (1) the root tip, (2) the region of root-hairs, (3) the region of root branches, and (4) the older part which gradually grows thicker.

We all know that the root absorbs water from the earth. This water is held between the fine particles of the soil, and so to absorb it the root must come in contact with the soil-particles. The root-hairs formed on the tender skin of the root can easily pass between these fine particles, turn and twist round them, as shown in fig. 26, and suck up the water like a sponge. But as the root grows its delicate tip

is pushed through the hard grains of the soil and continually wears away, but is as constantly replaced by the forma-

Fig. 23. A primary root with root-hairs.

Fig. 24. The same with adhering mud.

Fig. 25. A young Bean plant showing the tap-root with branches, h, root hairs, c, the cotyledons, p, the young bud.

tion of a tissue which surrounds it at the top like a cap. This is the root-cap. The tip of the root is also peculiarly sensitive to moisture and can at once perceive in what part of the soil there is water. It changes its course accordingly and thus arises the zig-zag form of the root (fig. 25). The root-hairs follow the root-tip and rapidly absorb water, but as the root elongates the delicate hairs are torn away and fresh hairs are continually formed just behind the tip. The older part of the root then throws out branches which serve not merely to fasten the plant securely to the earth,

but also repeat the boring and absorbing characters of the main root. ✕

Tap and adventitious roots.— The first root formed by the radicle is termed the *primary root*. In Dicots generally this gradually grows up into a long, stout root, termed the *tap-root*; its branches are the *secondary roots*. In large trees the tap root becomes enormously stout and long, and branching repeatedly, covers a large portion of the soil. A good form of tap root may be seen in many common Dicot herbs · Sunflower, Mustard, Natiya-sag (*Amarantus Blitum, var. oleracea*), etc. It is especially long in plants of dry open places where the upper crust of the earth is dry and the moist substratum is at a great depth. The root of Kantikary (*Solanum xanthocarpum*), or Sheal-kanta (*Argemone mexicana*) may be cited as an instance. In one plant, *Hardwickia binata*, found in the drier parts of Chota-Nagpur, *the seedling plant has a tap root no less than ten feet long!* The length of the tap root depends upon the depth of the sub-soil water.

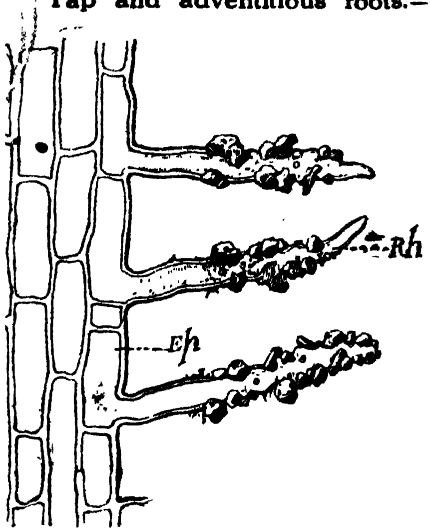
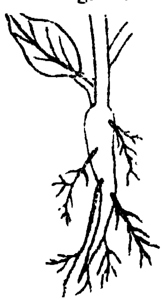


Fig. 26. Part of a longitudinal section of a very young root, highly magnified, showing the skin [Ep] bearing root-hairs [Rh] with adhering particles of the soil.

In Monocots, however, the primary root does not live long and cannot form a tap root. The first root formed

from the radicle perishes shortly after germination and newer roots spring from the lower part of the stem (fig. 22). They are termed *adventitious roots.* They are so called because they do not arise from the radicle from which the root-system of a plant is derived, but may arise from any part of the stem. In Grasses and cereals the root system is a collection of thin, long, *fibrous roots* (fig. 30) coming out from the joints of the stem. Similarly in Bamboos and the Sugar-cane the adventitious roots are formed in circles round the stem at the joints. In such Monocot trees as Palms (Cocoanut, Betel-nut) the root system is made up of long, unbranched, rod-like adventitious roots, some of which may be seen just coming out of the trunk and pointing downwards.

Fig. 27.



A tap root.

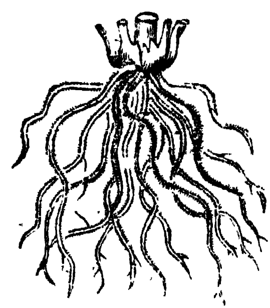
Fig. 28.

Conical root.

Fig. 29.

Fusiform root.

Fig. 30.



Fibrous root.

The primary tap root is the rule in Dicots and the Pines. But they may also produce adventitious roots. In fact all plants have a tendency to produce roots from parts of the stem which lie near a moist soil. And branches of certain plants, such as the Rose, the Marigold, the Jasmines, (Bel, Jui, etc), the Sajina (*Moringa pterygosperma*—the Horse-radish tree) etc., may be even severed from the

parent stock and planted separately; in a few days they produce adventitious roots from the cut end of the stem. Indeed these plants are mainly propagated by such *cuttings*.

Fig. 31. The Bot or Indian Banyan tree with prop roots.

Some very peculiar and gigantic forms of adventitious roots are formed in certain plants. In old Banyan (Bot, Aswatha) trees certain cord-like or columnar structures may be seen hanging from the boughs. These are roots which gradually grow vertically down until they reach the ground. They then penetrate into it, and growing thicker and thicker form very strong pillars for the heavy horizontal boughs of the tree. The Banyans live for hundreds of years and an old tree may have hundreds of such pillar-like roots, as shown in fig. 31. Such supporting roots are better known as **prop roots.** Another kind of supporting roots may be seen in the Screw-pine (Ketuky—fig. 32). The trunk of this tree produces a number of cylindrical adventitious roots which grow out obliquely pointing downwards and then reach the earth. From a distance the plant looks as if supported on several stilts, like a spider

standing on its long legs, and so those roots are sometimes called **stilt-roots.**

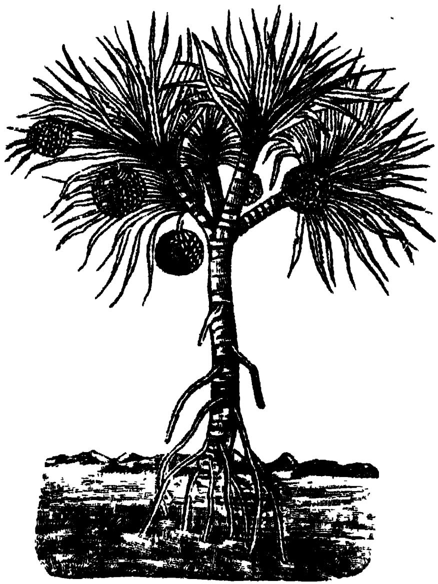


Fig. 32. The Screw-pine (Ketuky) with stilt roots.

Modified forms of tap roots.—Three special forms of tap root are shown in figs. 28, 29 and 33, *viz.*, the *conical*, the *fusiform*, and the *napiform*. The conical tap root, best seen in the Radish (Moola) has a large base and a tapering apex, with slender branch roots coming out of the sides. The fusiform root is tapering both ways with a swollen middle from which thin branches may be given off. It may be seen in the common Four o'clock (Krishna-Kali) plant, Punarnaba (*Boerhaavia repens*), Aconite, Palang or Spinach etc. The napiform root, as in the Beet or Turnip, has a very wide and swollen upper

portion, the lower end being drawn out like an ordinary long root.

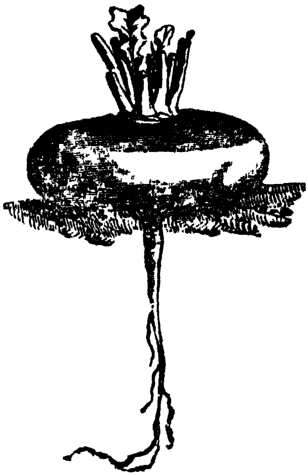


Fig. 33. Napiform root of Turnip.

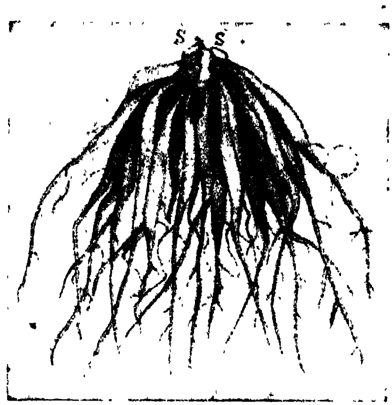


Fig 34. Fasciculate root of Satamuli

All the three forms are soft, fleshy, and succulent, not hard and wiry like ordinary roots. This is because these roots belong to a certain class of plants, called **biennials,** which convert their underground parts into store-houses of food matter. Biennials, well-known examples of which are the various roots used as vegetables, carrot, beet, radish, sweet-potato, sank-aloo and turnip, develop during the first year a very short stem with a crowd of leaves, and often a fleshy tap root in which food is stored. In cold climates in the second year an erect leafy stem bearing flowers is constructed at the expense of the food-materials stored up in the thickened roots ; fruits are produced from the flowers, and after the ripening of the seeds, the whole plant dies down together with the exhausted roots. Such plants are termed

biennials because they live and complete their life-work in two years or seasons. But in warm climates, such as in the plains of India, they are annuals, and the food stored up in the roots in the early part of their growth are used up later for the growth of flowers and fruits. Hence cultivators take care to harvest them for the market before they run to flower.

Other plants, called *perennials*, (p. 30) live from year to year, and have usually a cluster of fleshy roots. For instance, the Satamuli (*Asparagus*) has a cluster or *fascicle* of fusiform roots (fig. 34), hence called *fasciculate*; in Dahlia the roots are *tuberous*; in certain grasses they are *nodulose* (with small swellings), in others *moniliform* (with a chain of small bead-like swellings); and so on.

Growth of roots.—Roots branch in a fairly regular order. The youngest branch is nearest the tip of the main root while the older ones arise further and further away. The lateral roots are therefore said to arise in *Acropetal succession*. One important character concerning the origin of lateral roots is that they first arise inside the tissues of the main root, and then push their way through the rind of the latter. They are hence said to be *Endogenous* (arising within) in origin. Above and below each young lateral root the surface of the mother root will be found to be slightly split, denoting that the former has ruptured the latter as it forces its way outwards. This is not the way in which branches are formed on the stem. Stem-branches arise from the *outer* tissues of the mother-stem and are hence said to be *Exogenous* (growing outside) in origin.

Special forms of roots.—The great majority of plants are *land plants*, *i.e.*, they are fixed to the earth by means of roots. The two main functions of *subterranean roots*, or the roots of land plants are: (1) to fix the plant to the soil, and (2) to absorb water and other food matters from it. In the case of biennials and perennials the roots have an additional function, *viz.*, that of storage of reserve food. But there are other plants which differ in their mode of life from land plants. These have certain special kinds of roots.—

AQUATIC PLANT

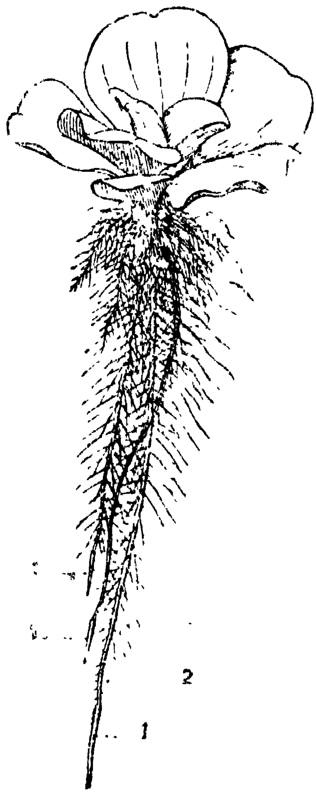


Fig. 35. The Bara-Pana—*Pistia Stratiotes*, showing the floating device. 1, 1, the Root-tip; 2, 2, the Root-hairs.

1. **Aquatic or floating roots** may be seen in the common *Pistia* (Bara pana), the Water-hyacinth (*Eichornia crassipes*), and other floating plants of ponds and ditches. They arise in clusters of long, white, delicate threads from the lower part of the stem, and spread out in all directions in the water. They thus prevent the plant from toppling over in strong current and wind, and act like a buoy. They do not penetrate into the soil and so do not perform the rough work of an ordinary root. A root-cap at the tip is thus unnecessary and is often not formed. Often they have no root-hairs but a copious branch system, and the work of absorption is done by all parts of the surface.

2. **Aerial roots**, or roots hanging in the air and not attached to the ground, are found in certain *perching plants* or air-plants, called *epiphytes*. These are plants which rest on the boughs of trees to the bark of which they bind themselves by certain roots and produce other roots, called aerial roots, which simply hang in the air. There are many Orchids and Aroids (*Philodendron*) which are epiphytes. The commonest instance is the Orchid *Vanda* (Rasna) found hanging from the boughs of many trees. The epiphytes have mostly to depend for their food upon the air, and the hanging roots can absorb the water-vapour from the atmosphere. These aerial roots have no root-hairs, nor root cap, are generally unbranched, and most remarkable of all, are commonly greenish like stems.

The term aerial root is often generally used for all roots which spring in the air, *e.g.*, the hanging roots of the Banyan which later on descend to the earth and form prop roots. But it is better to restrict the use of the term to the hanging roots of epiphytes.

3. **Parasitic roots** are found in *parasites*. These are plants which *live and feed* upon the juice of other plants by driving peculiar sucking roots into the latter. The nourishing or *host plant* is thus deprived of its own food and may be killed by the parasite. Thus the twiner *Cuscuta*

(the Dodder—Alkooshy-lata or Swarnalata), found extensively in thickets and hedges, has no leaves but only a yellow wiry stem which twines round the stems of other plants. Here and there the two stems are joined by a tissue which proceeds as a small swelling from the parasite and penetrates into the interior of the host plant. This tissue is the root of the parasite by means of which it absorbs all the food matter that it requires from the host. Parasitic roots (often called *haustoria*) are very soft and simple in structure, and are not at all root-like in appearance, for they only exist in the interior of other plants.

The Sandalwood tree (*Santalum album*) is a curious instance of a *root-parasite*. The tree has roots of its own in the ground, but when they come into contact with the roots of other plants, they attack them and suck food from them.

4. **Clinging or climbing roots** are found in *root-climbers*. For instance, the Betel (Pan) plant, as cultivated, is trained on sticks or poles to which the stem binds itself by little adventitious roots issuing from the joints. So also in the Pepper-vine (Golmurich), the Gaj-pippul (*Scindapsus officinalis*), and the large climbing Aroids (Kachoo family) found on trees.

SUMMARY.

The **Root** is an organ which serves to fix the plant to the soil and to absorb food matters from it, and is distinguished from the shoot in not bearing any leaves.

The first root of a plant is the primary root ; its branches are secondary roots. In Dicots the primary root forms generally a large and thick tap root with many branches. In Monocots it soon perishes and is replaced by a system of roots which arise not from the primary root but from the lower part of the stem. Such roots are termed adventitious roots. They may be induced to grow in many Dicot plants also, E. G, from cuttings or from stems trailing on a moist soil,

In typical tap roots four parts may be easily distinguished. These are: [1] the root cap which protects the tip of the root, [2] the root-hairs behind the growing tip, which absorbs moisture and food from the soil, [3] the root-branches arising further away, which serve to fasten the root more firmly, and [4] the oldest part which thickens and supports the trunk of the tree.

Kinds of root.—As there are several kinds of plants, such as land plants, water plants, climbing plants, and so on, so there are different kinds of roots.

1. *Subterranean roots* or those of land plants have ordinarily the four parts mentioned above. Dicot trees have an enormous tap root with many branch roots; Monocot trees, [Palms and Bamboos] have stiff adventitious roots arising in circles from the lower part of the stem. Dicot annuals have generally a short tap root with branches, Monocot annuals have always fibrous roots. Biennial and perennials have thickened and fleshy roots, [conical, fusiform, napiform, fasciculate, tubercular, etc.] in which large quantities of food matter are reserved.

2. *Aquatic* or floating roots are thin, delicate, and serve to keep the plant afloat. They have no root-cap, and root-hairs are more or less suppressed.

3. **Aerial roots* of certain epiphytes are unbranched, cylindrical roots which hang in the air and absorb nourishment from it. They have no root-hairs.

4. *Clinging* or climbing roots of certain climbers are short roots which bind the plant to a support. They have no root hairs.

5. *Parasitic roots*, or haustoria, are very tender cellular organs which penetrate the tissue of the host plant and feed upon its juice.

QUESTIONS.

1. What is a root and what are its typical parts? Describe how the root is adapted to perform its functions.

2. What are: prop root, adventitious root, fasciculate root, haustoria, perennials, stilt root, aerial root, epiphytes, biennials, parasites, and annuals? Describe their function. Give Indian examples.

3. Describe the root system of: Bamboo, the Indian Banyan, Betel, Radish, Mustard, Rice plant, Sugar-cane, Asparagus, Dahlia, Orchids, and the Screw pine.

4. Distinguish between the root systems of Dicots and Monocots generally.

5. Show how the form of the root is modified according to the function it has to perform.

CHAPTER III.

THE SHOOT.

Just as the radicle grows down into the root, so the plumule grows up into the shoot. The root grows downwards into the earth and avoids light, while the shoot grows upwards into light and air, and bears green leaves and also, after a time, flowers and fruits. An ordinary shoot consists of (1) the axis or the stem, (2) the leaves, and (3) the bud at the apex which continues the growth.

The shoot which springs directly from the plumule is the *primary shoot*; its branches are *secondary* or lateral shoots. The points from which leaves arise on the stem are termed *nodes*; the portion of the stem between two nodes is called an *internode*. A stem is made up of internodes. The bud at the apex of the primary stem is, in some cases (Palms), often the only bud which elongates the plant; if this is cut off the whole plant dies. In most plants, however, besides the apical bud other buds are formed at the axils of the leaves, *i.e.*, at the angle between the base of the leaf and the stem. These buds (called *axillary buds*) develop into branch-shoots.

Herbs, shrubs, and trees are readily distinguished. Trees are large woody plants the lower branches of which die off leaving a clear trunk, and live for many years. Shrubs are smaller woody plants which have no clear trunk but numerous branches arising from near the ground, and are hence of a bushy nature. Hedge-plants, such as Java (the shoe-flower) and Menthi (Henna—*Lawsonia innermis*) are typical shrubs. Herbs are smaller and softer plants, not hard and woody, and do not live long. Some like

the Banana are large and tree-like, but do not live for more than a couple of years. According to their duration of life, herbs may be *annuals* (Mustard, Rice, Pulses), *biennials* (Carrot, Radish, see p. 23), or *perennials* (Banana).

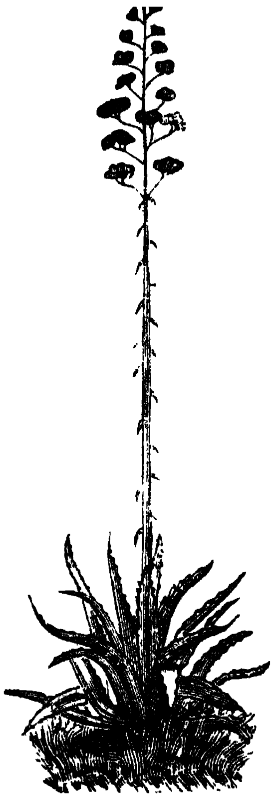


Fig. 36. The Century plant *Agave Americana.*

Annual herbs are those which germinate, grow, and conclude their flowering and fruiting within the course of a year, and after the ripening of their seeds, die away. Some annuals are very small, no bigger than a couple of inches, and live only for a couple of months. These are seen in meadows amongst the grasses. Others are very large and tree-like, such as the Castor-oil plant which lives for eight to ten months and then dies. Biennials (p. 23) are plants which require two years to complete their life. In the first season the seed germinates, produces the root and a small shoot, and stores up food matter; in the next season of the following year the food is used up in building a flower- and fruit-bearing shoot, and after the seeds are ripened the plant dies away. The food is stored in swollen roots or stems. The shoot of the first season has a short stem and large crowded leaves, while that produced in the next

season is a long flowering shoot almost without leaves. Perennial herbs live from year to year, the aerial shoot dies down periodically, and new shoots are formed every year from underground parts. The Banana is a perennial. It requires two years to form its flowers and fruit, and then it withers, but a number of young plants crowd around it by this time. The whole plant does not die, for a part of it remains buried in the ground, lives and grows in it, and every year throws up aerial shoots which produce the characteristic large leaves, flowers, and fruits. Other examples of perennial herbs are: the Water-lily, Lotus, Kachoo, etc.

In no plant is the stem developed uniformly from the base to the apex. Thus, in the common grass we find a brown stem trailing on the ground, from which springs a green aerial leafy stem and this terminates in the minute flowers so characteristic of grasses. Similarly if we dig up the Banana, the Canna, or the Ginger plant, we observe that the part of the plant which lies buried in the earth is thick and almost root-like, but up above it develops into a green leafy shoot which in time produces flowers at the top. In fact in many herbs we can readily distinguish three parts of the shoot, three stories so to say, following one upon the other :—

(1) The *underground shoot* buried in the soil.
(2) The *aerial leafy shoot* bearing green leaves, and
(3) The *flowering shoot* bearing flowers.

In trees and large woody plants the underground shoot is not recognisable, but in herbs it is often the most important and prominent part. In some herbs, such as the Onion, Bhoi-champa (Bhumi-champaka—*Kaempferia rotunda*), Gritakumari (*Aloe*), and Rajanigandha (*Polyanthes tuberosa*), the leaves are arranged in whorls (called *rosettes*) on the ground, and an aerial stem is not seen.

Such stemless plants are termed *acaulescent* (*a* = not, *caulis* = stem), and the leaves are called *radical*, since they appear to arise from the root. In reality they spring from the underground shoot. But though an aerial leafy stem is not formed, a long flowering shoot is produced at the time of flowering. Such a flowering shoot is termed a *scape*. The Pine-apple plant and the American Aloe (the Century plant—*Agave americana*—fig. 36) are other examples. The latter is a stout shrub which grows very slowly. It requires from 15 to 20 years or more until it is fully grown, and then very rapidly a lofty scape with hundreds of flowers is produced. After the seeds are ripe the whole plant dies away, but not before a crop of small rosettes is formed from the underground part around the base of the parent plant.

The **underground or subterranean shoot** is also called the *leaf-scale region* of the plant, because it bears scale-leaves and not ordinary green leaves. It is often thick and succulent as it acts as the storehouse of reserve food matters. These are manufactured mainly during the summer by the green leaves of the aerial stem, and are then conducted down into the underground shoot. Here they remain quietly deposited during the winter, and are spent next spring to build up new aerial shoots. The underground shoot

Fig. 37. Rhizome of Ginger.

is sometimes root-like in appearance, but is easily distinguished from its nodes and internodes, scale-leaves with

buds in their axils, and from the absence of a root cap at the growing apex. The following are some of the important modified forms.

1. The rhizome is an elongated root-like underground stem with distinct nodes and internodes, and small scale-leaves (fig. 37.) Ginger and turmeric, as we use them, are rhizomes: so too are the underground fleshy portion of the Mankachoo (*Alocasia indica*) and the Banana plants. The rhizome lies buried in the ground, more or less horizontally, and is often very thick as it stores nutritive matter. Slender and creeping rhizomes may be seen in many grasses, Ferns, and in the common Shoosny-shak (*Marsilia*). The scale leaves with their buds may be easily seen in young and fresh Ginger (fig. 37).

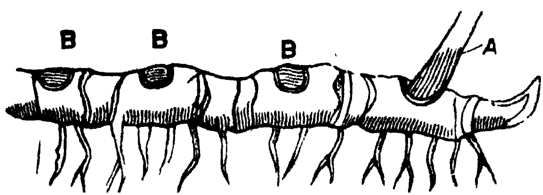


Fig. 38. A Rhizome [diagrammatic] showing at B the scar of the previous years' shoots, at A the new shoot of the year.

2. The tuber is another form of underground shoot. It has a short, swollen, and fleshy stem with minute scale-leaves. The potato is a tuber. On its surface there are several '*eyes*' or buds regularly arranged in little pits along the sides. The buds are protected by thin membranous scales which can be easily seen in young potatoes. The fleshy stem stores food matter at the expense of which the buds grow up into leafy sprouts. In cultivation the potato-tuber is cut up and small pieces with the 'eyes' are sown. In time the buds grow up into plants. When the plant is well developed, tubers are formed from the

Fig. 39. The Water-Lily – Shalook—*Nymphaea Lotus*, showing the stem which is a short thick rhizome with roots coming out from the joints.

ends of underground branches (stolons, p. 35) as shown in fig. 40. Tubers are also formed in certain other herbs, such

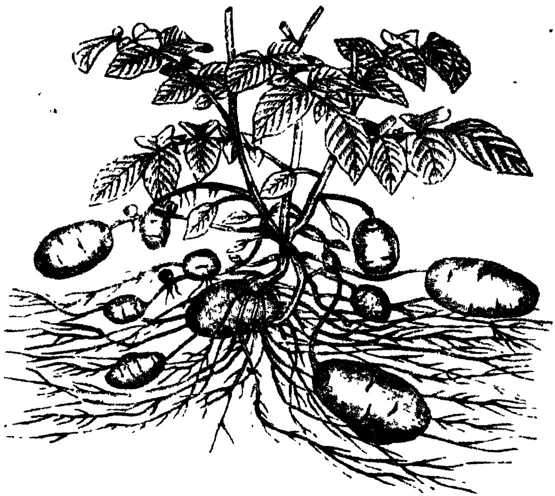


Fig. 40. The Potato plant with tubers.

as the Amada (*Curcuma Amada*—the Mango-ginger), Bhooi-champa (p. 30), Hansraj (*Hedychium coronarium*), etc.

The term "tuber" is especially applied to a stem-tuber which must be distinguished from a ROOT-TUBER (see p. 24). A stem-tuber differs from a root-tuber in having 'eyes' or buds on its surface.

The bulb is another form of underground shoot. It is a large subterranean bud. It consists of a small, flat, disc-like, or slightly conical stem from the upper surface of which arise large fleshy scale-leaves overlapping each other. In the rhizome and the tuber the stem is fleshy while the leaves are insignificant scales, but in the bulb the stem is very short while the scales are fleshy and store food matter. The short disc-like stem of the bulb is entirely covered by the scale leaves, so that the growing tip is not visible, but from the

lower surface of the stem-plate numerous adventitious roots are formed. The Onion and the Garlic are common examples.

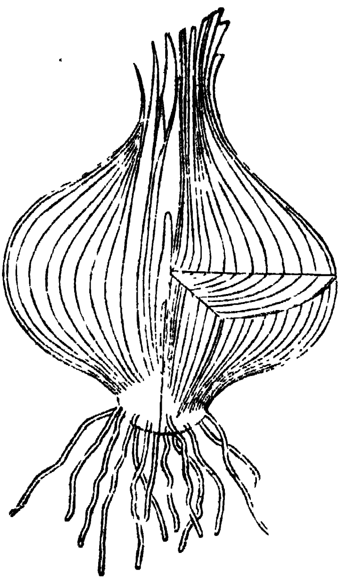


Fig. 41. Bulb of Onion cut to show the scale leaves.

Bulbs are either: (1) SCALY (fig. 43) where the scale-leaves only partially overlap at the margins (Garlic), or (2) TUNICATED, where they form complete sheathes, one inside the other (Onion). Other examples of bulbs are the Glory-lily (*Gloriossa*), the Spider-lily (*Hymenocallis*), the Sukha-darshan-lily (CRINUM), the Rajanigandha (*Polyanthes tuberosa*).

The corm is a large, thick, roundish underground stem with only a few scale leaves. It may be regarded as a condensed rhizome bearing buds and scale leaves at one part, either at the flattened top or at the side, and a crowd of adventitious roots at the bottom. The common Ol (*Amorphophallus campanulatus*) is a good example.

The **aerial shoot** is characterised by green leaves on its stem and usually terminates in flowers. The ***vegetative stem***, or that which only bears green leaves, is, as a rule, erect, but certain small plants are too weak to keep their stem erect. These may be either PROSTRATE and CREEPING, that is, lying or trailing at length on the ground and rooting at the nodes, or CLIMBING. Erect stems are of various forms: delicate or HERBACEOUS in herbs; thick, hard, and woody in trees and shrubs. The term culm is applied to the peculiar close-jointed

stem of Grasses and Bamboos. The internodes of a culm are commonly hollow. The thick, unbranched, columnar trunk of Palms, marked by the scars of fallen leaves, is termed a **caudex**. Dicot trees have, as a rule, a much-branched trunk. When the main trunk is undivided, long and mast-like, and the lateral branches are smaller and smaller the higher they arise on the main stem, so that the plant looks conical, it is said to be EXCURRENT. When, however, the main trunk soon divides, and the branch-trunks also constantly divide, so that the plant has a dome-shaped or rounded appearance, the ultimate branches or twigs hanging down, it is said to be DELIQUESCENT. The following are some of the common forms of weak stems.—

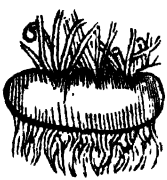


Fig. 42. A corm.

Fig. 43. Scaly bulb.

The **sucker** is a shoot which first arises as a branch from the underground stem of a plant, and then gradually comes out into the air a short distance from the parent plant. It then grows straight up, forms its own roots and green leaves, and lives like an independent plant, while the parent plant dies down. A common example is the Chrysanthemums (Chandra-mallika). These plants flower in winter after which the main stem begins to wither. By the next spring a crop of small plants with a crowd of leaves is formed around the main stem. They arise from the portion of the plant buried in the soil, from the buds in the axils of the scale leaves, thrive and spread on all sides all through the rains while the parent dries up or rots away, rapidly elongate and then produce flowers again in the next winter. Another good example of suckers is the Rose.

The **stolon** is another form of branch shoot. It arises

from the lower part of the aerial stem, from near the ground. It does not grow upwards into an erect shoot but bends

Fig 44 Fig. 45. Fig. 46

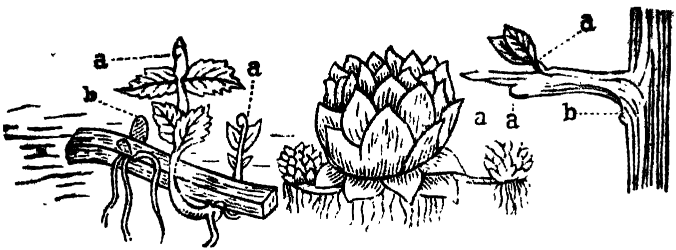


Fig. 44. A Sucker [a]. Fig. 45. Offsets [a]. Fig. 46. Thorn a,a, buds of which the upper one has developed a shoot; b, scar left by the subtending leaf.

down, touching the ground with its free tip, and striking root from below produces an erect shoot. The arched portion, or that connecting the parent and the daughter shoot, in time rots away and the two separate. The following are special forms of the stolon.

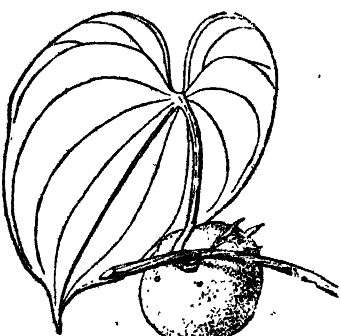


Fig. 47.
The Kham-aloo [Dioscorea]

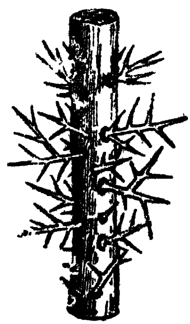


Fig 48.
Thorn of Pani-amla.

The runner is a very slender stolon with long, bare, thin internodes, which does not generally live long but perishes

in the course of a year. The common Kalmishak (*Ipomoea reptans*) and the Amrool-shak (*Oxalis corniculata*), for instance, rapidly spread themselves in all directions by means of runners. They first arise in spring from the axils of leaves of the parent, bend down and trail along the groun d, and produce small-scale leaves at wide intervals, from the axils of which are produced erect leafy shoots, while the nodes put out fibrous adventitious roots.

The offset is a thick and stout stolon. Its free tip turns up and produces a rosette of leaves above and a cluster of roots below (fig. 45). Many water-plants, such as the Pana (*Pistia*), the Water-hyacinth (*Eichornia*) the *Vallisneria etc.*, multiply very rapidly by offsets.

Fig. 49. The Torulata—*Quamoclit pinnata*, Boij—a twiner.

Fig. 50. The Moon-flower—*Ipomœa bona-nux*—a twiner

Climbing plants have relatively a thin main stem which is not rigid enough to remain erect and bear the weight of its branches and foliage. Most of the large jungle climbers are hard and woody, but their stem is only **FLEXIBLE** like a cable, and not like the trunk of trees. The reason why they climb is that like all plants they must have plenty of

air and light, and since their stem is not strong enough to remain upright, they manage by various means to climb over the tops of other trees, and thus secure for themselves the most advantageous position as regards air and light. The seedling of a climber growing at the foot of a tree has at first a thin long stem with only a few small leaves at great intervals, and it is not until the roof of the tree is reached that a crop of branches and large leaves is unfolded, so that the whole weight is borne by the sheltering tree Climbers may be.—

Fig. 51. The Lau—*Lagenaria vulgaris*—a tendril-climber.

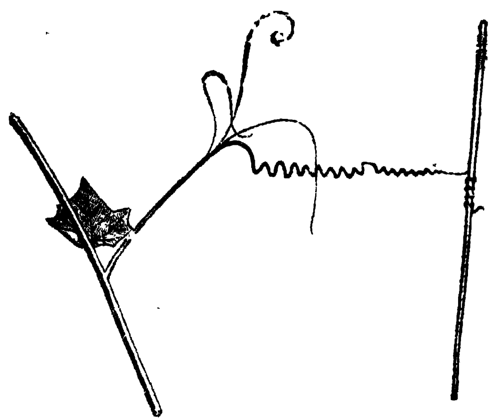


Fig. 52. The Dundul—*Luffa ægyptiaca*—a tendril-climber.

1. TWINERS. Twining plants have long slender stems which move slowly in the air and twine themselves round upright supports. Their tips, bare of leaves for a great length, may be seen nodding in the air, and if watched for several hours, may be observed to make a very slow sweeping movement through the air. Common examples are the Morning-glory, the Moon-flower, and other *Ipomœas*, the

Bean, the Aparajita (*Clitoria ternatea*), etc. Twiners may be: (1) DEXTRORSE, or those making clock-wise movement, from left to right (*Dioscorea alata*—kham-aloo), or more commonly, (2) SINISTRORSE, or winding anti-clockwise, from right to left (*Ipomœas*). Fig. 50.

2. ROOT CLIMBERS—(see p. 26).

3. TENDRIL CLIMBERS. These are plants which produce certain special twining organs called *tendrils* (p. 40). These are long, slender, whip-like bodies which slowly move through the air, and when a solid object, a twig, say, is found in the way, it is grasped (fig. 52) by coils thrown round it. Later on, the free part of the tendril lying between the climber and the support twists itself cork-screw fashion, or like a spring, and thus the plant is dragged towards the support to ensure safety.

4. STRAGGLERS OF SCRAMBLERS. These are climbers which ascend by simply stretching their growing tips through the forks and openings of the vegetation near-by. Their long slender shoots pierce the thickets and reaching the upper sun-lit area begin to spread out the branches and leaves, so that a slipping or sliding back is prevented. Commonly thorns, prickles, hooks, and similar organs are profusely developed, and these afford a further safe anchorage. The common Kantali-champa (*Artabotrys odoratissima*) is such a straggler with large beaked hooks (fig 56). The slender herb Lata-phatki (Naphatki—*Cardiospermum Halicacabum*) is another instance of a HOOK-CLIMBER. Examples of stragglers with thorns or prickles are the common Sheakool (*Zizyphus napeca, Wild*), the large BOUGAINVILLEAS (Bhuban-bilasy or Bagan-bilasy lata), the climbing Roses, and the Cane-palms of the Malaccas.

Modified Shoots—In some cases shoots or branches are greatly modified in shape and structure to perform certain special functions. The following are instances.—

1. **The thorn** (figs. 46, 48) is a hard, woody, pointed object which acts as a weapon of defence. It is a greatly suppressed and undeveloped branch. Examples:—the Bael (Bilwa—*Aegle Marmelos*), the Wood-apple (Elephant-apple—Kath-bel—*Feronia Elephantum*), the Pomegranate (Dalim), the Karamcha (*Carissa carandas*).

Thorns (also called stem-thorns) must be distinguished from other similar pointed structures called **spines** and **prickles**. Thorns are modified or undeveloped branches, and so are found in the axils of leaves or at the tip of a branch. They may be simple (Wood-apple), or branched (Bael). In *Gymnosporia montana* (BAIKUL, Hind), a shrub of dry regions, the thorns are large and even bear leaves and flowers. Spines (p. 66) are modified leaves or parts of leaves. For instance, the leaves of the common Jujube (Kool—Bayer—*Zizyphus jujuba*) have two small pointed bodies at their base; these are spines (stipulary spines, see p. 51), being parts of the leaf. Prickles are hard pointed bodies which arise irregularly from the surface of stem or leaves. They are neither modified stems nor modified leaves. They may be seen on the surface of the Rose (fig. 53), or the Brinjal plant.

2. **The tendril** is a long, filamentous, whip-like body which can twine round a support and thus help a plant

Fig. 53. Stem of Rose, showing prickles (h)

Fig 54. Coccoloba

Fig. 55 Flattened stem. (cladode) of Opuntia.

to climb. Stem-tendrils, or tendrillar shoots, which must be distinguished from leaf-tendrils (p. 66), may be seen in all plants of the Cucumber family (Cucumber, Gourd,

Pumpkin, etc.), and arise either in the axil of a leaf, or very near its base. The simplest case is seen in the Passion-flower (Jhoomko-lata) where they arise distinctly in the leaf-axils. In the Cucumber family the tendrils are often branched and stand just opposite the leaves. This is because they really represent the terminal part of a shoot which, being modified into a weak tendril, is pushed aside by the stronger branch developing from the axil of the leaf (p. 46).

Fig 56. The Kantali-champa (*Artabotrys odoratissima*)—flower-stalk with a hook.

Fig. 57. The Pea—a tendril climber.

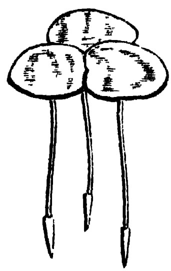
All tendrils are peculiarly sensitive to contact. If rubbed by the hard surface of a suitable support the tendril curves and throws a coil round the latter. At first this is loose but further rubbing tightens the grasp and fresh coils are formed. So long as the tendril is young, its tip slowly moves in circles in the air till a support is reached. Failing to get one, the old tendril merely rolls up and withers away.

The cladode or phylloclade is a flat leaf-like stem which assumes the functions of the green leaf. The common Phani-monsa (Nag-phani—*Opuntia Dilleni*) is made up of thick, flattened stems or cladodes, while the leaves are entirely modified into spines (fig. 55.) The aquatic Pana, known as the Duckwood (*Lemna*—Chota-pana), has only a slender

Fig. 58

Shoot of Asparagus

Fig. 59.

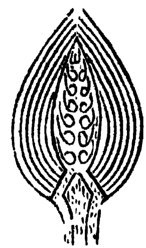


Cladode of Lemna

Fig. 60.

Terminal and axillary buds

Fig. 61.



Section through a bud.

shaft immersed and a flat, green, floating structure which is really the whole shoot of the plant modified into a cladode (fig. 59).

Many plants of the Mansa and Shij family (the spurges—*Euphorbia*) produce a thick and fleshy stem and very much reduced leaves which may either fall off early, or are converted into spines. In such cases the stem acts like the leaf. The garden plant *Coccoloba platyclada* (fig. 54) has flattened jointed stems or cladodes, and small leaves which remain for a short period only. In the *Asparagus* of the gardens the main stem and branches are elongated, but the leaves are reduced to mere spines (s, fig. 58) from the axils of which arise green needle-like branches. These are cladodes.

Buds are undeveloped shoots. The first bud of a seedling is the **plumule**; it gradually elongates and forms the shoot. The growth in length of a plant takes place mainly at the apex,

At the very tip of the stem the internodes have not yet elongated, the young leaves, which are in course of development, are crowded together and closely overlap the growing apex. This compact structure is the TERMINAL BUD (figs. 60, 61). Fig. 63 gives a magnified view of such a bud cut lengthwise. The very apex of the shoot terminates in a conical bulging

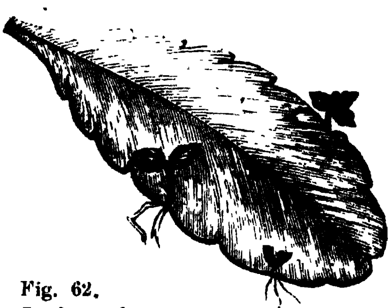


Fig. 62. Leaf of Bryophyllum showing adventitious shoots.

Fig. 63.

below which are the rudimentary leaves. The latter first appear as small conical protuberances, and become larger and larger the further removed they are from the apex. As the leaves grow more rapidly than the axis or the stem, they envelop the more rudimentary leaves higher up and, overarching the extreme tip, form a bud.

A bud, then, is a rudimentary shoot consisting of a small axis or rudimentary stem the internodes of which are not yet elongated, and numerous rudimentary leaves which are closely crowded and overlap the apex.

Branches of the main stem also make their first appearance as buds. These arise in the *axil* of the leaves, and may be traced back even in the bud. Fig. 63 shows the rudiments of branch-shoots just appearing in the axils of the

young leaves as small bulgings. These are the rudiments of axillary or lateral buds. As the lower leaves of a bud unfold and the internodes develop, these axillary bulgings grow up into AXILLARY BUDS (fig. 60, a), and in time elongate and produce branches.

The tip of the shoot, as has been seen, is naked, and not protected by a cap as in roots. Leaves and branches, so characteristic of the shoot also make their appearance as small out-growths from the surface of the young axis, *i.e.*, they have an external or *Exogenous* origin (cf. branch roots, p. 24).

The terminal bud elongates a plant, the axillary buds produce the branches, and these are the *Normal* buds of a plant, so called because they arise in regular order, in predetermined positions on the young parts of a plant. Sometimes, however, the axillary buds develop long after the subtending leaves have fallen away from the old and thicker parts of the stem. Such buds are called *Dormant buds.*

In contrast to normal buds are those which are formed not in the axil of leaves, or at the tip of the stem, but irregularly from the old or young portions of the shoot. These are *Adventitious* buds so called because they are formed out of the proper order. A common example is the pathurkuchi (*Bryophyllum*). The leaves of this plant are thick and juicy, and have marginal notches (fig. 62). If a leaf is placed covered with earth for several days, small plants appear at the notches. These leaf shoots are formed from adventitious buds.

In some plants buds appear more or less green and rapidly develop into a shoot. This may be observed in all rapidly growing annuals. Such buds are called *naked,* as opposed to those which open out only in spring and pass through a resting period in the winter or the dry season. Such buds are protected by brown or hairy scale-leaves and are hence called *scaly* buds ; *e. g.* Bamboo, Magnolias, Banyans.

Branching in higher plants is always MONOPODIAL (MONO=one, PODOS=leg), *i. e.*, a main axis gives rise to lateral branches from which, in turn, other branches are developed. This is best seen in such tall excurrent (p. 35) trees as Pines, Auraucarias, etc.

In many Cryptogams, the main axis does not branch *Laterally* as in the monopodial system, but splits its growing tip, as shown in fig.

65, from which the branches develop in the forked manner. This is known as the **dichotomous** (di=two, temnien=cut) type. The two forks may similarly divide at the tip, or only one may divide, either alternately right and left, as in fig. 66, or only to the right or the left, as in fig. 67. The former is called a **scorpioid** or sig-zag dichotomy, and the latter a **helicoid** or coiled dichotomy.

The **monopodial** branching of higher plants may be either (1) RACEMOSE. i. e., with the main axis continually elongating and the branches gradually growing acropetally from below upwards, or (2) CYMOSE, i. e., with the main axis soon arrested in growth while the branches outstrip it in growth. Figs. 68-71. Excurrent stems are racemosely branched, deliquescent stems or plants of a bushy nature branch in the cymose manner.

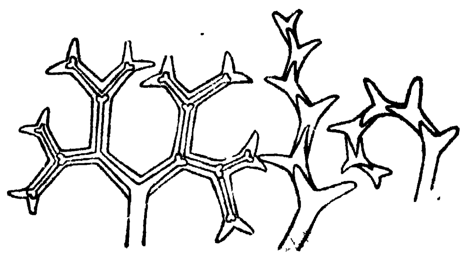


Fig. 65. Fig. 66. Fig. 67.

Two special forms of cymose branching are easily distinguished :—

1. In the first, two or more lateral branches, arising below the terminal bud of the main axis, may develop more strongly than the main axis, so as to overtop it, and each branch may be again similarly branched, and so on. When there are only two such branches below each terminal bud, the branching looks like a dichotomy as in fig. 65, and is called *False Dichotomy*. It differs from the true dichotomy in having an arrested stem at the top of the two lateral branches. When there are several such branches, the branching is a false polytomy (poly=many).

2. In the second type of cymose branching, only one lateral branch arises below the terminal bud, but so exceeds the main axis in development that its apex is pushed to one side, while the branch itself seems ultimately to become a prolongation of the main axis. This form of branching is seen more commonly in the flowering portion of the shoot,

and is shown diagrammatically in figs. 68 to 71. The axis which is thus formed from the union of branches of different order, and looks like a monopodial axis, is called a **sympodium** (syn=united,

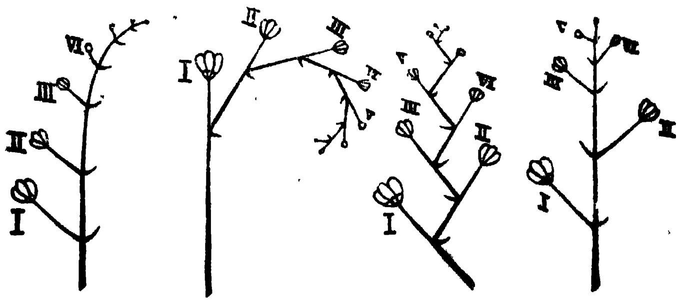


Fig. 68. Fig 69. Fig. 70. Fig. 71.

podos=leg). In many trees the terminal buds of each year's growth die, and the prolongation of the stem, in the following spring, is continued by a strong lateral bud, so that in a few years the sympodial nature of the trunk is not recognisable, and it looks like a monopodium. The tendrils of the Cucumber family are modified terminal shoots, while the axis of the plant is a sympodium formed by the strong branches which develop from the axil of the leaves and push aside the terminal tendrillar shoot (p. 40).

SUMMARY.

The **Shoot,** as distinguished from the root, is that part of the plant which grows upwards towards light and air, and has an unprotected growing point. Three regions of the shoot may be distinguished.—

A. The **underground shoot,** or the leaf-scale region.—This remains buried and bears scale-leaves. The modified forms are—(A) The *Rhizome*—a root-like elongated underground stem producing leafy shoots above and roots below. Ex. Ginger, Turmeric, Waterlily.

(B) The *Tuber*—a thick, fleshy, globose, underground stem with scaly buds on the surface Ex. Potato.

(C) The *Bulb*—a large, fleshy, underground bud. Ex. Onion.

(D] The *Corm*—a large, fleshy, underground stem with a few scale leaves. Ex. Ol.

B. The **aerial foliage shoot** or the region of green leaves. It may be—

1. *Erect.*—Special forms are—

(A) The *Caudex*—the peculiar unbranched trunk of Palms.

(B) The *Culm*—the jointed stem of Bamboos and Grasses with hollow internodes.

(C) *Excurrent* stem—an undivided mast-like main trunk with branches arising acropetally so that the tree is a huge cone.

(D) *Deliquescent* stem—a much-divided trunk with branches hanging down so that the tree is dome-shaped.

2. *Climbing*—Climbers may be—

(A) *Twiners* which twine the stems round supports—Bean.

(B) *Tendril-Climbers* which climb by tendril—Cucumber.

(C) *Root-Climbers* which climb by clinging roots—Betel.

(D) *Stragglers* which anchor themselves on hedges and thickets by hooks, thorns etc.—the climbing Rose.

(3) *Prostrate* or *creeping*, the special forms of which are—

(A) *Sucker*—a branch shoot originating underground and becoming aerial. Ex. Chrysanthemum.

(B) *Stolon*—an aerial branch which bends down, strikes root, and forms an erect shoot at the end.

(C) *Runner*—a long filiform stolon. Ex. Oxalis.

(D) *Offset*—a short thick stolon with a leaf-rosette at the apex. Ex. Pistia.

C. **The floral-shoot** or the region of flowers. (See Ch. VI.)

Some **modified forms** of the aerial shoot are.—

1. *Tendril* (stem-tendril)—a slender, leafless, filamentous body which coils round supports, Ex. Cucumber.

2. *Thorn*—a hard, sharp-pointed, undeveloped branch. Ex. Bilwa.

3. *Phylloclade* or *cladode*—a leaf-like flattened shoot. Ex. Opuntia, Lemna.

[4. *Flower*—which is really a modified shoot.]

Buds are undeveloped shoots. The first bud of the plant is the plumule. The bud consists of a rudimentary axis or stem with a naked tip, and a few rudimentary leaves which overlap each other and cover the axis. Buds are.—

A. *Terminal*, when at the tip of the stem.

B. *Axillary*, when in the axils of leaves.

C. *Naked*, when green and not covered by scale leaves.

D. *Scaly*, when protected by brown or yellow scale-leaves.

E. *Dormant*, when they remain undeveloped for years.

F. *Adventitious*, when they arise out of proper order.

CHAPTER IV

THE LEAF

A typical **green leaf** consists of three parts: (1) a flat expanded portion called the blade or *lamina*, (2) a leaf-stalk or *petiole*, and (3) the *base* of the leaf. In large leaves, such as those of palms, the leaf-base is large, expanded and boat-shaped. But in smaller leaves, such as those of many Dicots, the leaf-base is small and simple, and frequently bears two small outgrowths termed *stipules*. They may be easily seen in the common Cotton or the Bean plant standing one on each side of the petiole at its base. Leaves with stipules are called *stipulate*; those without stipules are *exstipulate*. The leaf-stalk or petiole

Peltate leaves.

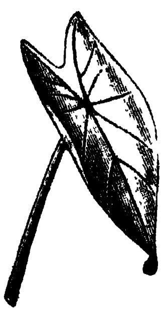


Fig. 72.
Leaf of Colocasia.

Fig. 73.
Leaf of the garden Nasturtium.

Fig. 74.
Leaf of Water-lily.

is not present in all leaves. When it is absent, as in the Zinnia, the blade of the leaf sits directly on the stem. Such a stalkless leaf is called *sessile*; a leaf with a stalk is *petiolate*.

The petiole serves to raise the leaf-blade and to hold it in the position best suited to get light. It also enables the blade to move freely so that it may not be torn by the wind. It is typically cylindrical, but a groove often runs on its upper surface making it slightly compressed and channelled. This is very prominent in the large leaves of Palms. In most leaves it is prolonged into the blade of the leaf as the midrib dividing it into two equal halves. In other leaves, as in those of Fan-Palms, it branches in the lamina into several strong ribs A leaf with a single midrib is callrd *unicostate*; that with several ribs is *multicostate* (*uni* = one, *multi* = many, *costæ* = ribs). As a rule the petiole is attached to the bottom of the lamina but in some leaves, as in those of the Lotus, the Water-lily, and the garden Nasturtium (*Tropæolum majus*), it is attached to the back of the lamina. Such leaves are called *peltate* (see figs. 72—74).

Stipules are small leaf-like outgrowths from the base of the petiole. Commonly they stand one on each side of the petiole. As a rule they are much smaller than the ordinary foliage leaves, from which they are also distinguished by their lateral position at the base of the petiole. They are sometimes minute and scaly but when large, as in the Pea (fig. 77), they frequently look and act like leaves. In some plants they cover and protect the young leaf-buds and fall off soon after the leaf unfolds. This may be seen in the Fig, the Jack, Magnolias and Chalta (*Dillenia*) trees. Stipules that fall off at an early period are said to be *deciduous*, those that do not are *persistent*. The following are some of the special forms of stipules.—

(1) FREE LATERAL stipules are the simplest and the most common form, as in the Cotton, Java (the Shoe-flower), Bean and other plants.

(2) FOLIACEOUS stipules are large and leaf-like. They are common in plants of the Pea family. In the common Pea (fig. 77) the two leaf-like bodies (a) which clasp the

Fig. 75. Fig. 76. Fig. 77.

Fig. 78

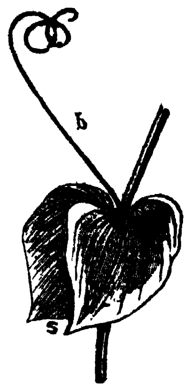


Fig. 75. A decurrent leaf. Fig. 76. Leaf of grass, (a) the ligule, (c) the node. Fig. 77. Leaf of Pea with foliaceous stipules (a). Fig. 78. Leaf of *Lathyrus aphaca* with foliaceous stipules and tendril.

stem are stipules, while the leaf (b) to which they belong is partly modified into tendrils (c). In Mussor-chana (*Lathyrus Aphaca*) the leaf-blade is wanting, the petiole forms a tendril (fig. 78, b), and the stipules (s) alone are developed as large green leaf-like organs.

(3) ADNATE stipules are those that adhere to the sides of the petiole and make it somewhat winged in appearance, as in the Rose (fig. 53,s).

(4) INTERPETIOLAR stipules lie between the petioles of two leaves standing opposite to each other at the same height on the stem, as in the Coffee plant, Rangan (*Ixora coccinea*), Gandharaj (*Gardenia*). They are sometimes large, leaf like, and form with the leaves a whorl round the stem, as in the Munjeet (*Rubia cordifolia*). Fig. 79,

(5) OCHREATE stipules (fig. 80) form a hollow tube, called *ochrea*, surrounding the portion of the stem just in front of the petiole, as in Pani-marich (*Polygonum serrulatum*).

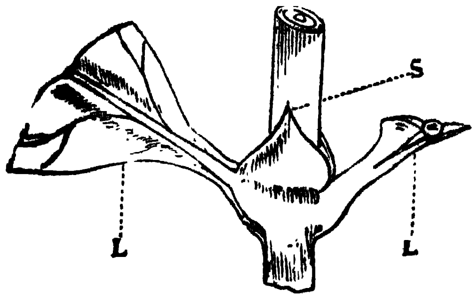


Fig. 79. Interpetiolar stipules (S) between two leaves (L).

(6) TENDRILLAR stipules. Sometimes the stipules are modified into long tendrils, as in the Sarsaparilla (*Smilax*) family.

(7) SPINOUS stipules may be seen in *Capparis spinosa* (*Vern*. Kabra), and in some plants of the Babla (*Acacia*) family.

Stipules are rare in Monocots. The leaves of Monocots have commonly an expanded base which partly or wholly

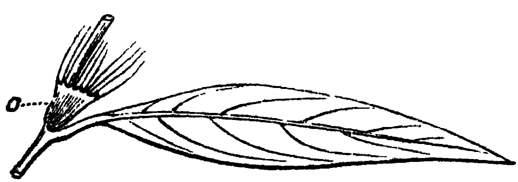


Fig. 80. Leaf of Polygonum with ochrea (O).

embraces the stem. In grasses the petiole is represented by a complete sheath rolled round the stem, and at the point where the lamina bends away from this tube there is a little

membranous or hairy scale termed the *ligule* (fig. 76, a). The grass leaf is hence called *ligulate*. The ligule prevents rain water or dew from collecting in the sheath of the leaf, and thus protects the delicate stem from rotting.

In a few Dicot plants, as in those of the Carrot and Anisi family, and in Kalajira (*Nigella sativa*), the base of the petiole is sheathing or enlarged as in Monocots generally.

The leaf-blade or the lamina is of the utmost importance to the plant, for it is here that food matters are prepared. It consists principally of two tissues: (1) a soft green tissue (called *chlorenchyma*) which prepares food matters, and (2) a system of strands, known as the *veins* or *nerves* which appear to spread in the lamina like tiny threads. The latter project more or less from the surface, specially on the lower side, where they often stand out as long white strands. When a leaf is crushed between the fingers the soft green tissue is easily destroyed but the veins remain as fine threads. The veins consist of long tubes through which water and other food matters travel. They appear very distinctly when a thin leaf is held up to light. It may then be seen that they proceed from the petiole or from the midrib, and by constant branching spread in every direction in the lamina. Their ramification is best seen in withered leaves of the sacred Banyan (Aswatha), the Teak, or the Bean. In such leaves only the delicate framework of veins remains while the soft green tissue rots away.

The veins not only conduct food matters to and away from the leaf-blade but also help to make it rigid and flat. They are so distributed and ramified in the lamina that it is not easy for the wind to tear it. The petiole also serves to prevent the tearing action of the wind, for the lamina can easily flutter and turn about with the slightest breeze. In some large leaves, as in those of the Banana and certain Palms, the lamina is easily torn into strips by wind and rain,

or during growth, but after once torn they offer less resistence.

Venation, or the arrangement of the veins in the lamina, is of two principal types. If we examine the leaf of a grass or of a bamboo we find that the veins run parallel to one another from the base to the apex. This sort of venation is said to be *parallel*, and the leaf is described as *parallel-veined*. This is the type in almost all Monocots. But in Dicot plants the veins are not parallel. They form a very complicated net-work, as may be seen in the leaves of the sacred Banyan. Hence the venation is said to be *reticulate*, and the leaf is described as *net-veined*.

Kinds of parallel venation.—In the leaves of many Monocots, as in those of Banana, Canna, Ginger and Lilies, there is a strong midrib continuous with the petiole, and the smaller veins run parallel from the midrib to the margin on either side. This is the *unicostate* type. In the leaves of other Monocots, as in Grass, Bamboo, Sugarcane and Cereals, there is no single midrib but several ribs run parallel from the base to the apex; they are connected to each other cross-wise by numerous small veins. In Fan-Palms, on the other hand, numerous strong ribs spread away from the top of the petiole like the fingers of an outstretched palm, and the portions of the lamina supported by these ribs are traversed by innumerable smaller veins running parallel to the ribs. This is the *multicostate* type.

Kinds of reticulate venation.—In most net-veined leaves we can easily distinguish a midrib which continues the leaf-stalk and divides the lamina into two symmetrical halves. Branches arise from this midrib like plumes on the shaft of a feather and thin out by repeated branching right and left into the lamina giving rise to a net-work of weaker veins. This venation is said to be *pinnate*, and the leaf is described as *penni-nerved* or *feather-veined*. In

broad and large Dicot leaves, such as those of the Cucumber, the Papaw, the Lotus, and the Castor oil plant, there is

Fig. 81. Fig. 82. Fig. 83. Fig. 84. Fig. 85.

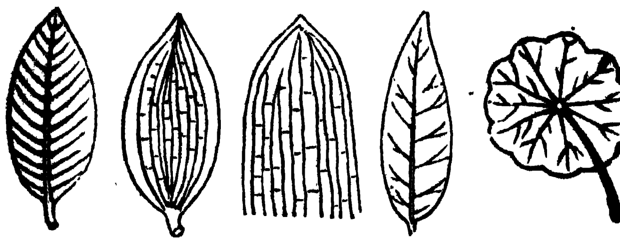


Fig. 81. Unicostate parallel venation. Figs. 82, 83. Multicostate parallel venation. Fig. 84. Reticulate venation—pinnate type; Fig. 85. Reticulate venation—palmate tape.

no single midrib, but the leaf-stalk divides at once in the lamina into three, five or more ribs which spread out like the fingers of the palm. Each rib bears side-ribs on both sides which by repeated branching form a net-work. This type is called *palmate*, and the leaf is described as *palmately-veined* or *palmi-nerved*.

The form of the leaf-blade may be—

1. LINEAR or very narrow and long, of almost uniform width, as shown in fig. 86, as in grasses and the rice plant.

2. LANCEOLATE or lance-shaped (fig. 87) a long and narrow leaf tapering each end, especially towards the top, as in the Bamboo.

3. OBLONG (fig. 88) or wide and long and blunt at the top, as in the Mango.

4. OVAL OF ELLIPTICAL, somewhat like an ellipse in outline, as in the Indian Banyan (Bot); fig. 88.

5. OVATE or egg-shaped, a wide leaf with oval base and narrow top, as in the Sacred Banyan; fig. 89.

6. ORBICULAR, ROTUND or round, as in the Lotus, the garden Nasturtium; figs. 73, 74, 85.

7. CORDATE or heart-shaped, a wide leaf with the base forming two lobes on the two sides of the petiole, as in the Betel, the Sunflower.

Figs. 86, 87. Fig. 88. Fig. 89. Fig. 90. Fig. 91. Fig 92.

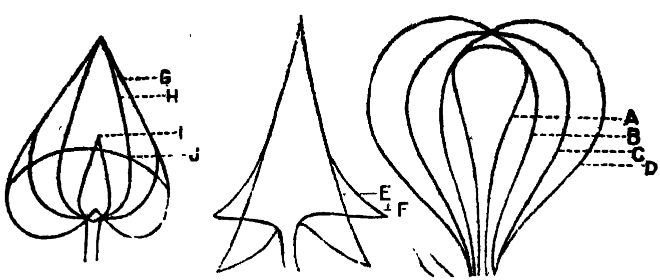
8. RENIFORM or kidney-shaped, a cordate leaf rounded at the top and much wider than long, as shown in fig. 111.

9. SAGITTATE or arrow-shaped, as in Colocasia (Kachoo, fig. 72).

10. HASTATE, a similar leaf but with lobes pointing outwards as shown in fig. 94. F.

11. RHOMBOIDAL or four-sided, as in the Water-chestnut (Pan-phal).

Fig. 93. Fig. 94. Fig. 95.



Figs. 93—95 Diagrams to illustrate leaf-outline. A, spatulate; B, oblanceolate; C, obovate; D, obcordate; E, sagittate; F, hastate; G, cordate ovate; H, lanceolate; I, subulate; J, reniform.

12. CUNEATE or wedge-shaped.

The outline of some leaves is just the reverse of the above. Such leaves are named with the prefix *ob*. Thus the leaflets of the Amrool (*Oxalis*, fig. 113) is obversely cordate, the apex instead of the base being lobed; it is *obcordate*. Similarly leaves may be *oblanceolate*, *obovate*, *oboval*, and so on. A *subulate* leaf is a small stiff awl-shaped leaf (fig. 93). A *spatulate* leaf is shaped like a spatula. A leaf is *unsymmetrical* or *inequilateral* *i.e.*, the two sides unequal by the much greater development of one side, as shown in fig. 92. This is characteristic of Begonias.

Fig. 96. The Poppy Plant.

Sessile leaves have sometimes a broad cordate base, so that there are ear-like lobes at the two sides of the stem (see fig. 80) Such *auriculate* or *eared* leaves occur in the common Akanda (the Madar— *Calotropis gigantea*). Sometimes a sessile leaf clasps the stem so as to surround it, as in the Poppy and the Rape. Such a leaf is called *amplexicaul* (fig. 96). A leaf is *decurrent* when the lamina adheres to the stem and runs down it so as to make it winged for a short distance (fig. 75). A needle-shaped leaf, like that of Pines is *acicular*.

The apex of a leaf may be (see fig. 97).—

1. *Cuspidate*, or ending in a sharp rigid point (I).
2. *Mucronate*, or ending in a narrow soft point (H).
3. *Acute*, or ending in a sharp acute angle (B).
4. *Acuminate*, or ending in a long drawn out tip (A).
5. *Obtuse*, or ending in a blunt angle (C).

6. *Truncate*, or with a flat end, as if the apex is cut off (D).
7. *Retuse*, or with a slight depression over the midrib (E).
8. *Emarginate*, or with a large depression over the midrib (F).
9. *Obcordate*, or with two large lobes at the top (G).
10. *Tendrillar*, or ending in a tendril, as in Gloriosa (fig. 103).

Fig. 97. Diagrams to illustrate the leaf-apex.

A B C D E F G H I

The **surface** of the leaf may be—

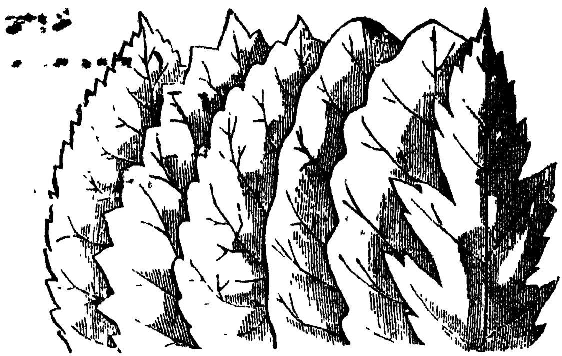
1. *Glabrous*, or smooth and even, as in Mango, Vinca.
2. *Rough*, or uneven and coarse, as in Fig, Indian Banyan.
3. *Pubescent*, or clothed with short downy hairs, so that the leaf is silky to the touch, as in Til (*Sesamum*).
4. *Villous*, or clothed with long curled hairs.
5. *Tomentose*, or clothed with long wooly felted hairs.
6. *Glaucous*, or covered with a white bloom, as in Cabbage.
7. *Glandular*, that is having glands containing oils or such things, as in Toolsy (the Basil), Lemon.
8. *Spinous* or *prickly*, I.E., armed with spines, as in Kantikary (*Solanum xanthocarpum*).

The **margin** of the leaf may be—

1. ENTIRE, that is perfectly even, as in the Jack, the Banyan.
2. SERRATE (fig. 98 A.), that is cut like the teeth of a saw, the teeth being turned upwards, as in the leaflets of the Rose.
3. DENTATE (B), that is with large teeth pointing outwards as in Java.
4. CRENATE (C), that is with rounded teeth, as in Thulkury (*Hydrocotyle asiatica*—fig. 111).
5. WAVY (D), or *Sinuous* (E), that is with slight and broad shallow depressions, as in the Devdaru (*Polyalthia longifolia*).
6. SPINOUS, that is with sharp pointed processes, as in Sheal-kanta (*Argemone mexicana*).

7. **Incised**, that is cut into segments by deep incisions as shown in fig. 98F.

Fig. 98. Leaf-margins.



A B C D E F

When the teeth themselves bear finer teeth the margin becomes *biserrate, bidentate, bicrenate*, etc. In incised leaves the margin is deeply cut. When the segments of an incised leaf are rounded, it is called *lobed*, as in the Melon (Torbooz), the leaf of which is palmately lobed. When they are pointed and the cuts do not reach half-way down the midrib, the leaf is called *pinnati-fid* or *palmati-fid* according as the venation is pinnate or palmate. When the cuts go more than half-way, the leaf is either *pinnati-partite* or *palmati-partite*; and when almost to the midrib, or to the petiole, it is either *pinnati-sect* or *palmati-sect*, according to the venation. Thus Cotton leaf is palmatifid; Castor-oil leaf is palmatipartite; Papaw leaf is palmatisect and the lobes pinnatisect, and so on.

Sometimes the lobes of a simple leaf are irregular and unequal. For instance the lower leaves of the Mustard plant have deep marginal cuts so that there are several small lobes ending in a large lobe at the top. Such a leaf

is described as *lyrate* (fig. 99) from its resemblance to a lyre. A *runcinate* leaf is very much similar but the lobes are pointed as shown in (fig. 100). A palmatisect leaf when like

Fig. 99. Fig. 100. Fig. 101. Fig. 102. Fig. 103.

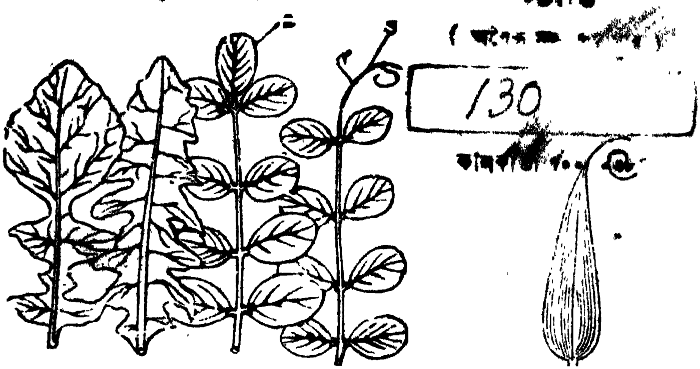


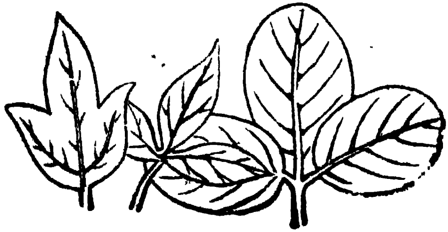
Fig. 99. Lyrate leaf. Fig. 100. Runcinate leaf. Fig. 101. Imparipinnate leaf. Fig. 102. Cirrhiferously pinnate leaf. Fig. 103. Leaf of Gloriosa ending in a tendril.

the claw of a bird, as shown in the diagram (fig. 91), is also called *pedate* or *pedatisect*.

Simple and Compound leaves.—The simplest leaf is that in which the blade has an *entire* margin, *i.e.*, it is not toothed or lobed. In other simple leaves the margin is cut up, so that the blade is lobed or incised. But however deep the cuts the segments of a simple leaf are joined. Thus the leaves of the Papaw and the Castor-oil plant are deeply incised, but they are still simple. When however the leaf-blade is broken up into distinct and separate *leaflets* the leaf becomes compound. Thus the leaf of the Rose (fig. 53) has a stipulate base, a long petiole, and separate leaflets seated on it; it is a compound leaf. Fig. 104 shows a simple palmatifid leaf, fig. 105 a simple palmatisect leaf, and fig. 106 a compound leaf with three leaflets. In a compound leaf

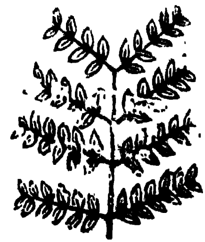
the main petiole bears branch petioles or *petiolules* supporting distinct leaf-blades called leaflets.

Fig. 104. Fig. 105. Fig. 106.



From simple to compound leaf.

Fig. 107.



Bipinnate leaf.

Compound leaves may be of the *pinnate* or of the *palmate* type. In a pinnately compound leaf the petiole is elongated and is pinnately branched, so that the leaflets follow one another on the petiole, as in the Rose. In a palmately compound leaf the petiole branches at its tip palmately, so that all the leaflets spring from the tip of the petiole (fig. 109), as in the Shimul (Silk cotton).

A compound leaf with numerous leaflets as in the Sajina (*Moringa pterygosperma*), is sometimes mistaken for a branch. To distinguish such a leaf from a real branch it should be remembered that: (1) a compound leaf, like a simple leaf, may bear a bud or a branch at its axil; (2) its base may be stipulate or expanded, not free and rounded as in a branch, (3) it has no terminal bud as in a branch, and (4) the *apparent* leaves (really leaflets) have no buds in their axils as true leaves have.

Pinnately compound leaves:—(1) A compound leaf is *pari-pinnate* when the leaflets are even in number, being arranged in pairs on the *rachis* or midrib, as in the Tamarind, the Gold Mohur, (*Poinciana regia*—Krishnachura), the Kalkashinda (*Cassia sophora*—Kasondi).

(2) A pinnate leaf with an odd unpaired terminal leaflet is called *impari-pinnate* (fig. 101), as in the Rose, the Marigold, the Aparajita (*Clitoria ternatea*—Sankapuspa).

(3) When a pinnate leaf ends in a tendril it is *cirrhiferously pinnate* (fig. 102), as in the Pea (fig. 77).

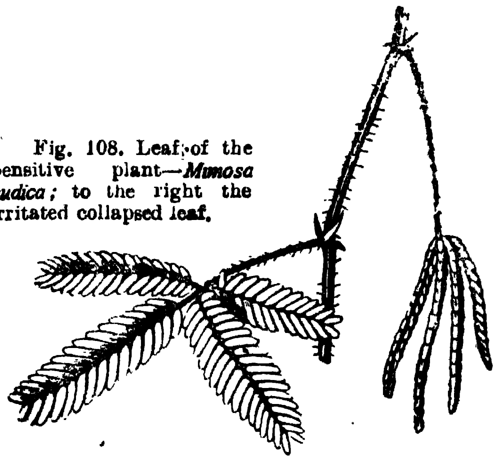


Fig. 108. Leaf of the Sensitive plant—*Mimosa pudica;* to the right the irritated collapsed leaf.

(4) A pinnate leaf may be twice compounded, *i.e.*, the main petiole may bear branch petioles on which the leaflets are pinnately arranged, as shown in fig. 107. Such a compound leaf is called *bipinnate*. This is common in the Babla (*Acacia*) family. Sometimes a leaf is thrice compounded in the pinnate manner, *i.e.*, it is *tripinnate* as is Sajina (fig. 115). When the division goes beyond the third degree (fig. 114) the leaf is called *decompound* as in Anise. In the Sensitive plant (*Mimosa pudica*—Lajjabaty, Lajuk) the main petiole bears four petiolules which spread out from its tip, and on these leaflets are arranged in the pinnate manner (fig. 108). Such a leaf is termed *digitately pinnate.*

Palmately compound leaves:—Palmate, or digitate leaves are those which have a number of distinct leaflets arising from the tip of the petiole. Thus.—

(1) A BIFOLIATE leaf has two leaflets, as in *Hardwickia binata* (Anjan). fig. 110.

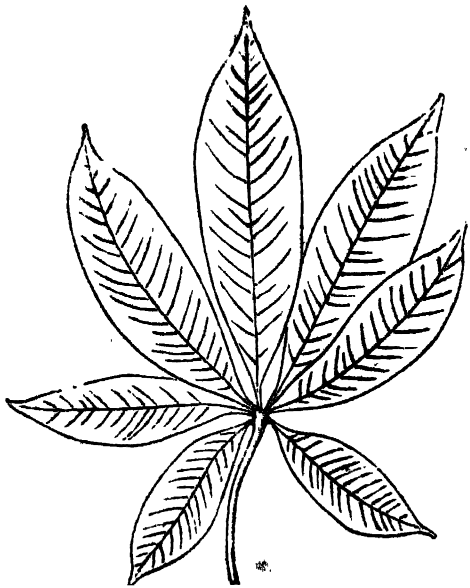


Fig. 109. Leaf of the White Cotton tree—*Eriodendron anfractuosum*—digitate leaf with seven leaflets.

Fig. 110. Two-foliate leaf of *Hardwickia.*

(2) A TRIFOLIATE leaf has three leaflets, as in Amrool-shak (*Oxalis*), the Bean.

(3) A QUADRIFOLIATE leaf has four leaflets, as in Shooshny-shak (*Marsilia*).

(4) A PENTAFOLIATE leaf has five leaflets, as in Hurhu-riya (*Gynandropsis pentaphylla*).

(5) A HEPTAFOLIATE leaf has seven leaflets, as in the Indian hemp (*Cannabis sativa*).

(6) A BITERNATE leaf is one which is twice compounded ternately. as in the Bael (*Ægle Marmelos*).

(7) A TRITERATE is thrice ternate, and so on.

Special form of leaves:—1. SCALE LEAVES occur generally on all underground shoot. The 'eyes' of potato are small buds covered by thin scales. The pulps of Onion, Garlic, Rajanigandha (*Polyanthes tuberosa*) etc., are made up of fleshy scales. Scale leaves are also found in the aerial shoot where they form bud-scales protecting buds.

2. ENSIFORM LEAVES are very long and flat like a sword. They have no petiole, nor a midrib, and stand almost erect. For instance, the leaves of the common Hogla (*Typha elephantina*, the Elephant grass or the Bulrush) are some six to eight feet long and one inch broad, and stand almost vertical like a drawn sword.

3. EQUITANT LEAVES are vertical like the last but are folded lengthwise on their middle like a folded note-paper. They are split only at the base, and being crowded the outer leaves bestride or embrace the inner ones. They may be seen in the common garden plant *Gladiolus* and are characteristic of plants of the Iris family.

Fig. 111. Fig. 112. Fig. 113.

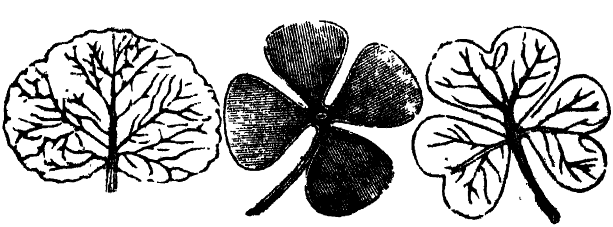


Fig. 111. Reniform leaf of HYDROCOTYLE ASIATICA with crenate margin.
Fig. 112. Compound leaf of MARSILIA with four leaflets
Fig. 113. Compound leaf of OXALIS with three obcordate leaflets.

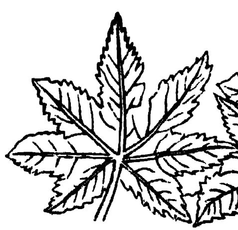
Fig. 114.

A decompound leaf

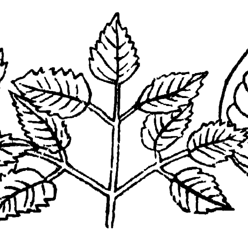
Fig. 115.

Tripinnate leaf of *Moringa pterygosperma.*

Fig. 116. Fig. 117. Fig. 118.



Palmatifid leaf.



Biternate leaf.

Unifoliate leaf.

4. HETEROPHYLLY.—In certain water-plants, e.g., the Water-chestnut (Paniphal—*Trapa bispinosa*), there are two kinds of leaves: (1) the *floating leaves*, which are flat and large with a swollen bladder-like spongy petiole which serves as a float, and (2) the *submerged leaves* which

are *dissected* or cut up into numerous thread-like segments. Such a condition is known as heterophylly. Fig. 119 shows a plant (*Limnophila polystachya*, Benth) which is amphibious, that is, half submerged and half aerial. The lower leaves are submerged and dissected, while the upper aerial ones are quite like ordinary leaves. There are many such heterophilous plants (Limnophila) in swamps and rice-fields. Floating leaves with a swollen bladder-like

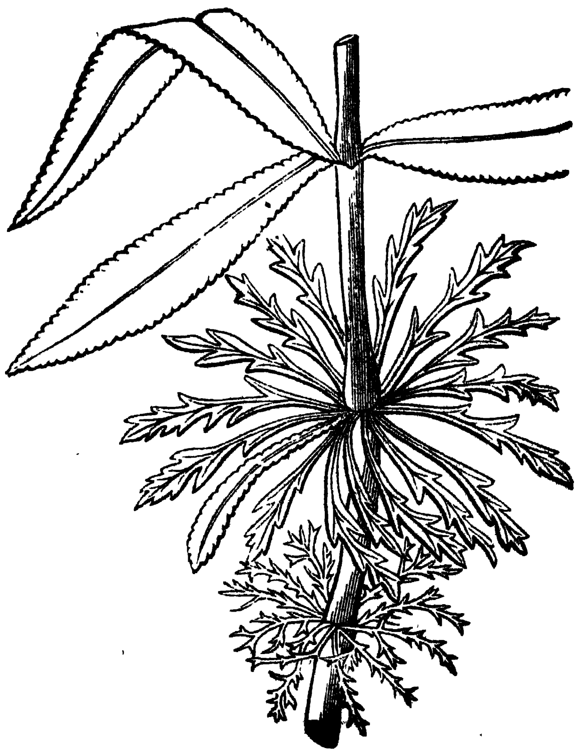


Fig 119. *Limnophila polystachya*, Benth. The lower two whorls are the submerged dissected leaves.

petiole may also be seen in the water-hyacinth (*Eichornia Crassipus*) which is very common in stagnant waters. Submerged leaves are not always dissected. In many plants which are totally submerged, *e.g.*, the common *Vallisneria* of ponds, the leaves are thin and long like a ribbon.

5. The leaves of Lemon and Orange (fig. 118) have a distinct articulation between the lamina and the petiole which is expanded like a wing. Such leaves are by some regarded as compound and are described as UNIFOLIATE.

Modified leaves.--(1) Many tendril-climbers modify their leaves into TENDRILS. These leaf-tendrils (see stem-tendrils) are very sensitive of contact with a hard object which is soon clasped by coils thrown round them. This is seen in the compound leaves of the Pea, the upper leaflets of which are tendrils (fig. 77). In the Mosoor-chana (p. 50, fig. 78) the whole leaf is reduced to a tendril, while the large stipules act as leaves. In the Gloriosa of the gardens, however, only the apex of the leaf is a tendril (fig. 103).

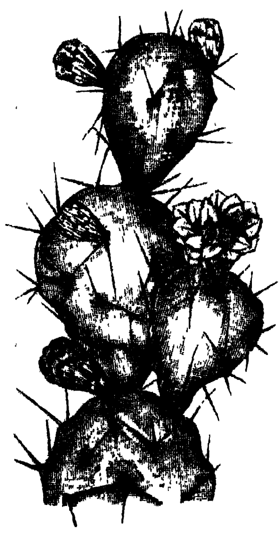


Fig. 120. The Phani-monsa —*Opuntia Dillenii*—showing the spines.

(2) Sometimes leaves are partly or wholly converted into hard pointed structures called SPINES. Thus the leaves of the Sheal-kanta (*Argemone mexicana*) are armed with sharp marginal spines. In the Phani-monsa (*Opuntia Dillenii*)

no leaves are formed; they are entirely modified into spines. In *Berberis asiatica* (Daruharidra, used in Hindu medicine), a mountainous plant, the leaves of the main stem are entirely transformed into 3-5-partite spines and from their axils condensed leafy branches are formed.

Fig. 121. The Sheal-kanta with spinous leaves.

(3) PHYLLODES are flattened leaf-like petioles without the lamina. They occur in certain Australian Acacias where the lamina is so little developed that often nothing remains but the flattened petiole which thus assumes the form and function of the leaf blade.

In certain plants, called insectivorous plants on account of their feeding on insects, the leaves are modified into special organs by means of which they can seize and then digest small insects. These are discussed in the chapter on nutrition under Physiology (part III). Other modified leaves, such as floral leaves and bract leaves, are described in the following chapters.

Classification of Leaves.—COTYLEDONS or seed leaves. These are the leaves of the embryo. They serve to provide nourishment to the young seedling, either by storing food matters, or by digesting and absorbing food matters stored in the seed.

2. SCALE-LEAVES (cataphylls or cataphyllary leaves), found as a rule on underground stems, also on some aerial stems, as in the young culm of bamboos. They serve to protect the young buds of a plant.

3. FOLIAGE LEAVES, or the ordinary green leaves of plants.

4. BRACT LEAVES (hypsophylls), or certain special leaves which protect flowers.

5. FLORAL LEAVES (anthophylls and sporophylls), or the leaves which make up a flower.

Duration of leaves.—Every year new leaves unfold in spring and old ones fall off. In some trees, such as the Silk-cotton, the leaves fall off

very early so that the plant is leafless for some months (winter) of the year. Such leaves are called DECIDUOUS. In other plants (Banyan, Mango) they remain throughout the year and fall off only when the new ones are becoming developed in spring. Such leaves are called PERSISTENT, and the plants are therefore called EVERGREENS. In many Pines, which are typical evergreens, the leaves remain attached to the plant for several years though new leaves are developed each season.

Arrangement of leaves in the bud :—In a bud the young leaves are packed away as compactly as possible in order to economise space. The arrangement of the leaves of a bud with respect to one another is called AESTIVATION. It may be: (1) OPEN, when the leaves forming a whorl are not in contact by their margins, (2) VALVATE, when the edges just touch but do not overlap, and (3) IMBRICATE, when they overlap one another by their margins. The manner in which each leaf is tucked up in the bud is termed VERNATION. It is—

(1) CONDUPLICATE, when the two halves of the lamina are folded together along the midrib, as in the leaflets of Rose.

(2) PLICATE or PLAITED when the leaf is folded several times along several ribs like a closed fan, as in the Palms.

(3) CIRCINATE, when the leaf is rolled down from apex to base like the tail of a dog, as in Ferns.

(4) CONVOLUTE, when the lamina is rolled from one margin to another length-wise, as in the Banana.

(5) REVOLUTE, when it is rolled downwards from each margin towards the midrib, so that the upper surface is external, as in *Nerium odorum* (Karabi.)

(6) INVOLUTE, when the lamina rolls upwards from each margin towards the middle, as in the Water-lily.

(7) CRUMPLED, or irregulary folded, as in Cabbage.

SUMMARY.

98 A typical green leaf has three parts: (1) the leaf-stalk or *petiole*, (2) a leaf-blade or *lamina* and (3) two outgrowths from the base, called *stipules*. The petiole and the stipules are not always present. A leaf without a petiole is sessile, one with the petiole is petiolate. A

leaf without stipules is exstipulate, one with stipules is stipulate.

The **lamina** is the most important part of the leaf. It has (1) a green soft tissue which prepares food matter, and (2) a number of veins which conduct food matter and also keep the lamina flat and firm. The arrangement of the veins in a leaf is called *venation*. It may be

Parallel (Monocots), or Reticulate (Dicots)

Parallel (Monocots)		Reticulate (Dicots)	
Unicostate, with one midrib (Banana)	Multicostate, with many strong ribs (Palms)	Pinnate, with a midrib (Sunflower)	Palmate, with several strong ribs (Papaw).

Stipules are leaf-like appendages of the leaf-base. They commonly arise in pairs on the two sides of the petiole. The following are the special forms.—

1. Foliaceous stipules, as in the Pea.
2. Adnate stipules, as in the Rose.
3. Interpetiolar stipules, as in the Rangun.
4. Ochreate stipules, as in Polygonum.
5. Tendrillar stipules, as in Smilax.
6. Spinous stipules, as in Acacia.

What do they do?—They protect the young bud. They are therefore wont to fall off, or shrivel, soon after the leaf has opened out, but the special forms mentioned above commonly persist throughout the life of the leaf, for they have to perform more important work than mere protection. For instance, the large stipules of Pea prepare food matters like leaves; the stipules of Smilax help the plant to climb: those of Acacia act as weapons of defence, and so on.

The main types of leaves are: (1) seed-leaves, (2) scale leaves, (3) foliage leaves, (4) bract leaves and (5) floral leaves.

Foliage leaves are either **simple** or **compound**. In a simple leaf the petiole is unbranched and bears only a single blade; in a compound leaf the petiole is branched into *petiolules* each of which bears leaflets.

Simple leaves, whether stalked or sessile, are of various forms. Large and broad simple leaves are often lobed or incised.

Compound leaves are either pinnate or palmate. In a pinnately compound leaf the petiole is elongated as the rachis, and from this branches or petiolules arise acropetally like plumes on the shaft of a feather. In a palmately compound leaf the main petiole ends abruptly in a number of petiolules. A pinnate leaf may be more than once compound; it may be bipinnate, tripinnate, and so on. A simple

pinnate leaf is pari-pinnate when the leaflets are paired; impari-pinnate when there is an unpaired terminal leaflet; cirrhiferously pinnate when it ends in a tendril. A palmately compound leaf, commonly also called digitate leaf, is bifoliate, trifoliate, quadrifoliate, etc., when the number of leaflets is two, three, four and so on respectively.

QUESTIONS.

1. What are the part of a typical leaf? What do you call the leaf in which one or other of these parts is absent?

2. What are the veins of a leaf? Describe the various ways in which veins are distributed in the lamina.

3. What are stipules? What is their function? Name the principal forms of stipules.

4. What is venation? Describe the venation in the leaves of (a) Date Palm, (b) Sunflower, (c) Grass, (d) Cucumber, (e) Lily, (f) Water-lily, (g) Banyan, (h) Papaw. Give diagrams.

5. Explain;—sessile, exstipulate, lanceolate, reniform, pubescent, orbicular, multicostate, reticulate, glaucous, cordate, serrate, pinnatifid, acicular, tomentose, crenate, obovate, peltate, auriculate, deciduous, ensiform, decompound, amplexicaul, equitant, and digitate leaves. Give examples and diagrams where possible.

6. Name the various forms of simple leaves.

7. Enumerate the various forms of compound leaves

8. How would you distinguish a simple from a compound leaf? Examine the following leaves and say whether they are simple or compound;—Papaw, Castor-oil, Cocoa-nut, Marigold, Rose, Nim, Potato, Tamarind.

9. In what respects do Dicot leaves differ from those of Monocots?

10. How may the leaf be modified to act as a climbing organ; What is heterophylly? Give instances.

11. Examine and describe in technical language the leaves of: Bamboo, Brinjal, Cucumber, Lotus, Mango, Pea, Mustard, Silk Cotton, Anise.

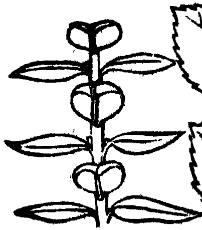
12. Describe the various kinds of leaves that may be found in a higher plant and the functious that they perform.

CHAPTER V.

PHYLLOTAXIS.

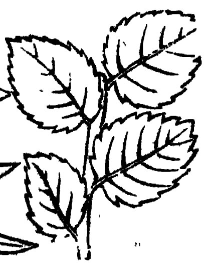
The order of distribution of leaves on the stem is termed PHYLLOTAXIS. There are three principal types of leaf-arrangement: (1) when the leaves stand alone, one only occuring at a node, they are said to be ALTERNATE or SCATTERED; (2) when two leaves stand at the same level, one on each side of the stem, they are OPPOSITE; and (3) when more than two originate from one node forming a circle or whorl round the stem (fig. 119), the leaves are called WHORLED or VERTICILLATE.

Fig. 122.



Opposite decussate leaves.

Fig. 123.



Alternate leaves.

Alternate leaves are variously arranged. Sometimes they are truly alternate; that is, the second leaf is exactly on the other side of the stem from the first. The leaves thus stand on only two vertical rows on the stem: the 1st, 3rd, 5th, 7th, etc., leaves standing in one row, and the 2nd, 4th, 6th, etc. leaves on the other row. Such leaves are termed DISTICHOUS or TWO RANKED, and may be seen in all Grasses, Bamboos and cereals. In some cases, as in Sedges and other Monocots, the leaves stand on three vertical rows, so that starting from one leaf the fourth stands just vertically over it. The 1st, 4th, 7th, etc. leaves stand in one row; the 2nd, 5th, 8th, etc. stand on a second; and the 3rd, 6th, 9th, etc. leaves on the third. This

arrangement is called the TRISTICHOUS or THREE-RANKED arrangement (fig. 124).

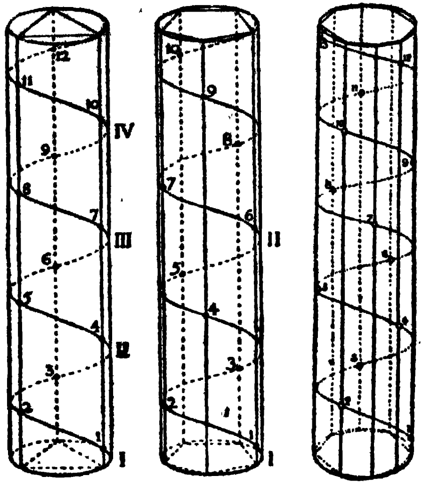
When a line is drawn round the stem so as to pass regularly from leaf to leaf, we find that its course is SPIRAL. This line will form on horizontal projection a coil, as shown in figs. 127-30, and is known as the GENETIC SPIRAL. The vertical lines on the stem on which a series of leaves, as mentioned above, lie are termed ORTHOSTICHIES. These are always equidistant, that is, they divide the circumference of the stem into a number of equal segments. The symmetrical appearance of a shoot is due to this fact.

In the two-ranked (DISTICHOUS) case, the spiral line commencing at any given leaf completes one circuit and commences a new one at the third leaf. In the three-ranked (TRISTICHOUS) arrangement, the spiral completes one circuit and commences a new one with the fourth leaf. The fraction of the circumference of the stem which lies between one leaf and the next (measured on a horizontal plane) is termed the ANGULAR DIVERGENCE. This in the distichous case is one-half, in the tristichous, one-third. These fractions are instructive. The numerator (1) indicates the number of turns of the spiral forming a complete cycle, while the denominator (2 or 3) expresses the number of leaves (and also the orthostichies) in that cycle. The angle subtended by the leaves at the axis or centre of the stem is, in the first case, half of 360° = 180°, and in the second, one-third of 360° = 120°.

In the PENTASTICHOUS or five-ranked arrangement of leaves the conditions are more complex. Here the sixth leaf stands over the first or the starting leaf, and begins a second story which ends at the 11th leaf. (Fig. 125). There are consequently five vertical rows or orthostichies on which

the leaves lie: *viz.*, the first with the 1st, 6th, 11th, etc. leaves; the second with 2nd, 7th, 12th, etc.; the third with 3rd, 8th, 13th, etc.; the fourth with 4th, 9th, 14th, etc.; and lastly, the fifth with the 5th, 10th, 15th, etc. leaves. The spiral line starting from a given leaf completes a CIRCUIT round the stem after passing the next two leaves, as shown in fig. 125, but the CYCLE is not completed till it passes through the 4th and 5th leaf, and finally reaches the 6th. Here the cycle is completed and a new one begins. This arrangement is represented by the fraction 2/5; the number (2) indicating the number of turns round the stem to complete the cycle, and the denominator (5) the number of leaves (and also the orthostichies) in the cycle. The angular divergence is two-fifth of $360^{\circ} = 144$. The two-fifth or pentastichous arrangement is common in Dicots, and may be observed in the Crotons, the Banyans, Java, Sunflower, and so on.

Fig. 124. Fig. 125. Fig. 126.



The OCTASTICHOUS or eight-ranked arrangement is where eight vertical rows of leaves on eight orthostichies exist, and the ninth leaf, starting from a given leaf, stands over it (fig. 126). There are thus eight leaves in the cycle.

In this case the SPIRAL takes three turns round the stem as it comes to the 9th leaf or completes a cycle. The phyllotaxis is represented by the fraction 3/8 indicating that there are eight leaves in three complete turns of the spiral, and that the angular distance between any two successive leaves is three-eighth of 360°. This type is not very common.

Fig. 127. Fig. 128. Fig. 129. Fig. 130.

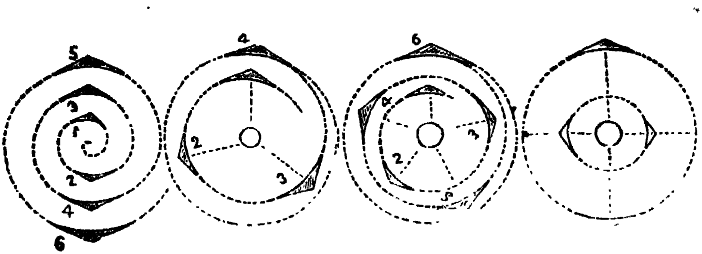


Fig. 127. One-half alternate or spiral phyllotaxis. Fig. 128. One third spiral arrangement. Fig. 129. Two-fifth phyllotaxis. Fig. 130. Opposite decussate phyllotaxis.

Opposite leaves stand at the same level on the stem with their nodes springing from its two sides. The circumference is thus divided into two equal parts, and the leaves may all lie on two vertical rows only. This occurs in many plants, *e.g.* in Rangun, Gandharaj, Kadamba, etc. The pairs of opposite leaves, however, commonly alternate, that is, they cross at right angles, the third pair standing over the first. Such leaves are called DECUSSATE (see fig. 122). Instances are the Toolsy, the Bakash, the Jasmines, etc.

Whorled leaves.—In some plants leaves arise in whorl of three, four, five or more. For instance, in the Saptaparni (*Alstonia scholaris*—Chattim, *sapta*—seven, *parna*—leaf), there are generally seven leaves forming a whorl at the top of the branches. The tree itself has a characteristic appearance, for the branches spread out horizontally in whorls of three or five, forming tiers a few feet apart. Generally

when the leaves are whorled, the leaves of one whorl stand over the intervals between those of the next whorl, but on the same vertical line with the leaves of the third whorl. In other words, the whorls ALTERNATE. In fig. 119 is shown an aquatic plant (*Lymnophila*) with whorls of three leaves. In some trees a number of leaves appear to spring from one point, as in the Pines, where the short branches commonly end in three long, slender, needle-like leaves in a cluster. Such leaves are called FASCICULATE, and the cluster a FASCICLE. In the Pines the fasciculate leaves really belong to a branch the inter-nodes of which are not developed; so they all spring from one point, as the bud from which they originate does not elongate, and a few membranous sheathing scales surround the base of the fascicle.

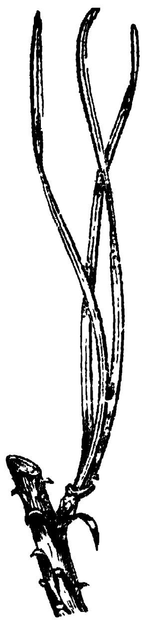


Fig. 131. Fasciculate leaf of Pine.

Advantage of phyllotaxis.— Observation of leaf-arrangement in different plants shows that generally leaves which are large and broad follow the half or one third plan, while those that are narrow are crowded and have the two-fifth or three-eighth arrangement. Thus climbers generally have large broad and cordate leaves which are disposed on two or three rows on the stem; that is, their phyllotaxis is either half or one-third. Generally speaking, as the leaves are more narrow, such as lanceolate, linear, acicular, etc. their phyllotaxes are represented by fractions of increasing complexity, such as two-fifth, three-eighth, and five-thirteenth, etc.

Leaves are so arranged that they do not shade those above or below them more than is absolutely necessary.

For, light is of the utmost importance to them and hence they economise space. Broad leaves if crowded too much would throw each other in the shade much more readily than if they were kept widely apart. The widest angular distance between two leaves is 180°, and this explains why most climbers have the distichous phyllotaxis. Again, narrow leaves if allowed to grow at wide intervals would leave large sunlit areas unused, and so they become crowded with two-fifth, three-eighth, or more complex phyllotaxes, being placed not on two or three vertical rows, but on five, eight, or more vertical lines on the stem. The principle appears to be: if the leaves are large, scatter them widely; if small and narrow, crowd them according to the degree of narrowness.

Many herbs exhibit a difference in the size and position of their foliage. The lowest leaves near the ground are the largest or have long petioles, those next above are visibly shorter, and often in the region of the flower, are changed into very small leaves or into mere scales. The leaves near the ground may be spread almost flat, or slightly bent down, while those higher up stand erect horizontally, the younger leaves at the top being obliquely bent upwards. This may be easily observed in the Sunflower plants. By this arrangement is secured a better illumination of all the leaves, for the top leaves can not overshadow those growing below. In plants, however, which have incised, lobed, or compound leaves, there is little danger of injury from shadow cast by the upper leaves, for enough sunlight can pass between the lobes and segments to the leaves below. The strips of shadow thrown on the lower leaves move their position along with the sun and remain at one spot only for a short time. Hence it is that in plants with much divided or compound leaves all the full grown leaves are of equal size and length, and stand out from the erect stem at about

the same angle. For similar reasons certain plants of the Aroid (Kachoo family) have perforations in the leaf-blade through which light can easily pass. Branches and horizontal

Fig. 132. A trailing plant forming leaf-mosaic on the ground.

twigs also attain the most advantageous position by twisting their internodes or petioles, or by adjusting their length, so that they come out of the cover of the overlying leaves. In this way small plants and climbers, especially trailing plants, expose their foliage fully to light and air.

Leaf-mosaic.—The arrangement of small and large leaves on the same shoot is very beautiful in certain plants growing in dark or half-shaded places. The larger leaves leave gaps between them and these are filled by smaller leaves which twist and turn so as to leave no gap unoccupied. The result is a mosaic-like fitting of leaves of various size and shape, so that a continuous green surface, as shown in fig. 132, is exposed. Such leaf-mosaics may be seen in many plants which trail over walls or in shady places. In the common Four-o'clock plant (Krishnakali.—*Mirabilis Jalapa*) an almost similar fitting of large and small leaves may be observed. In the Water-chestnut (Paniphal) the floating leaves form dense rosettes on the surface with large and small blades fitting closely together, so as to present a continuous green surface to light.

CHAPTER VI.

INFLORESCENCE.

Flowers often arise in clusters, because the flowering shoot (see Chap. III) is more freely branched than the vegetative shoot. A branch-system bearing flowers is termed an **inflorescence.** As commonly understood, an inflorescence is a collection of flowers. The number of flowers in an inflorescence is very variable, *e.g.*, three only in the common Jasmines, several thousands in certain palms (Date, Fan palm).

The axis of an inflorescence (called also the RACHIS) is generally the continuation of the vegetative axis. In certain herbs, such as the Onion, the Lily, Bhoichampa, Rajanigandha, etc., (see acaulescent plants) there is no foliage stem, the leaves form rosettes, and the stem of the plant lies underground ; but at the time of flowering a long stem springs from the centre of the leaves and bears only flowers. This is called a SCAPE. It is an elongated flowering shoot without any foliage.

Flower-buds, like leaf-buds, often arise in the axils of leaves which are here of a different form and function, and are called BRACTS, or bract-leaves (*hypsophylls*). Flowers subtended by bracts are called BRACTEATE, those that have no bracts are EBRACTEATE. Some flowers, such as Java, Morning-glory, Datura, arise singly from the axils of the ordinary foliage leaves, and are hence termed SOLITARY and axillary. The Bract, however, is a leaf peculiar to the inflorescence, and serves mainly to protect the flower while still in bud.

A branch may subtend a whole cluster of flowers, and then the diminutive term *bracteole* is applied to the small bracts, often in pairs, which lie at the base of the individual flowers.

A flower-bud may be either SESSILE or STALKED; in the latter case the stalk is called the PEDUNCLE, and in a much-branched inflorescence, the slender stalk of the individual flowers are called PEDICELS.

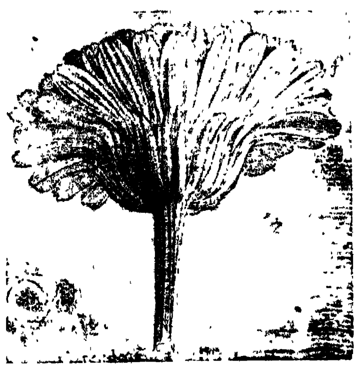


Fig. 133. A capitulum; in, the involucre of bracts; f, the flowers.

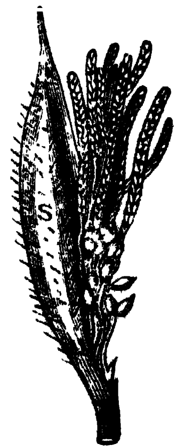
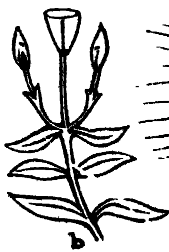


Fig. 134. Inflorescence of a Palm—S, the spathe.

Bracts are special leaves found in the flowering portion of a shoot. Their function is mainly to protect the flower-buds from rain, dew, heat, etc., and from undue radiation and cooling at night. They subtend either individual flowers or a whole inflorescence. Sometimes they are green, like ordinary foliage leaves, though much smaller, as in the Bakash (*Adhatoda Vasica*). Here the vegetative stem bears large cordate leaves, but terminates in an inflorescence easily recognised from the small green leaves which overlap like the scales of a fish. These overlapping leaves are bracts, and each bears a sessile flower-bud in its axil. Almost similar IMBRICATING bracts may also be observed in other plants of the Bakash family (*Acanthaceae*), and in the common *Commelinas*.

In many Monocots, a large bract subtends a whole inflorescence and forms a boat-shaped sheath, termed a SPATHE. This may be seen in the common Kachoo (figs. 135, 138) and also in many Palms (fig. 134). The flowers of these plants are very small, and



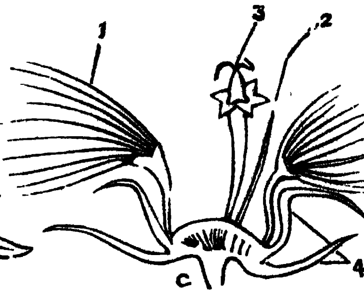


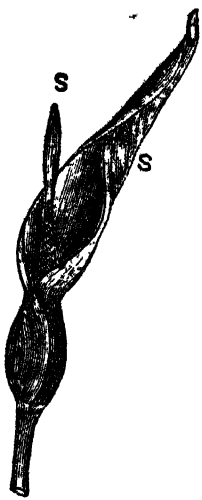
Fig. 135. Fig. 136. Fig. 137.

Fig. 135. Spathe (cut open) and spadix of *Colocasia*. Fig. 136. A typical cyme of three flowers—a dichasium. Fig. 137. A capitulum cut vertically—c, the rachis; 1, ray florets; 2, the palea subtending 3, the disc-floret, 4, involucre (diagrammatic).

form dense clusters which are covered and protected by the spathe. In some plants of the Kachoo family (*Aroids*) the spathe is a flat, white, or rose-coloured leaf which is very attractive, and for this the plants are extensively cultivated in the garden. Such *coloured* spathes are also seen in the Banana. The flower-cone (mocha) of the Banana (fig. 140) consists of numerous large, imbricating, boat-shaped bracts, each with a row of flowers in its axil. As the cone grows, the bracts open and stand up one by one and expose their axillary row of flowers, while their inner scarlet lining serves to attract insects. The upper surface is grooved so that rain or dew is easily drained off.

Coloured bracts, called petaloid bracts, are also found in the common garden plant Lal-pata (*Euphorbia pulcherrima*), where a whorl of vermilion-coloured leaves spreads out from the top of the branches and

bears a small, green, cup-shaped body in the centre. The leaves are bracts, while the central cup is really an inflorescence. In another common garden plant, the Bhuban- or Bagan-bilasy-lata, a huge thorn-climber (p. 39), there are three rose-red bracts forming a whorl, and each bears a small greenish flower. The cluster looks like a single flower, the bracts appearing like petals or the coloured leaves of a flower. The three flowers at the centre are inconspicuous, but the bracts serve to make them prominent and attractive to insects. This is another useful purpose served by these bracts.



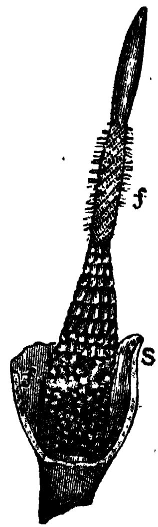


Fig. 138. Fig. 139.
Inflorescence of Colocasia (Kachoo). Fig. 138. Entire, with spadix (S) and spathe (S). Fig. 139, same with spathe (S) partly removed ; f, f, the flowers.

In some plants small green bracts are collected together in dense whorls or spires just below a group of flowers. Such a whorl is called an INVOLUCRE. It may be seen in the Sunflower, Dahlia, Marigold, Zinnia, Chrysenthemums, etc. (fig. 133). The flowers of these plants are densely crowded on a flat rachis (fig. 137,c) and the bracts form an involucre (4). A much less dense involucre is seen in the Carrot and Anise family.

The husks of paddy are bracts. Such stiff, chaff-like,

small bracts are called PALEÆ or GLUMES. They are found in Grasses, cereals and Bamboo. In the Sunflower and other plants of the family, the small flowers are individually subtended by white, membranous, scale-like bracts or paleæ. This may be seen by cutting the inflorescence vertically into two and then carefully removing the small florets. (as in fig. 137).

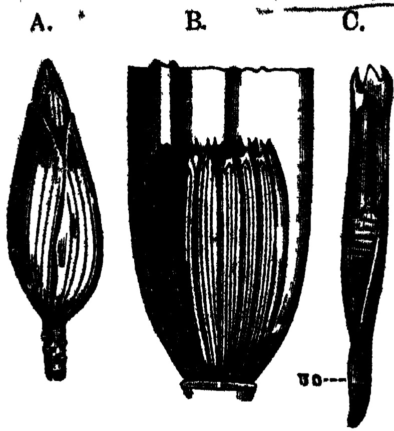


Fig. 140. Inflorescence of Banana. A, flower cone (Mocha), B, a single spathe with a row of sessile flowers, C, a flower.

Types of Inflorescence.—The various forms of flower-clusters may be placed under two principal types the RACEMOSE and the CYMOSE, according to the system of branching (see p. 45). In a typical raceme, as in the Mustard and the Radish, the flowers open gradually from below upwards, as shown

Fig. 141. A typical raceme.

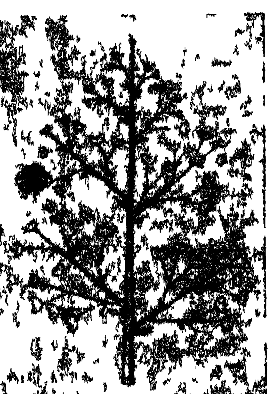


Fig. 142. A panicle

in fig. 141, that is, while the first flowers are just opening, the axis goes on growing and forming small flower-buds near the tip. In a typical cyme, as in the Jasmines (Bel, Mallika), the flowers open gradually from above downwards, as shown in fig. 138; that is, the axis forms a bud first at the top and then smaller buds lower down. In the first case, the growth of the axis is continued even after the first bud or flower is formed; in the second the formation of a flower-bud at the top of the axis terminates its further growth. Hence the racemose is also called the INDEFINITE, and the cymose the DEFINITE inflorescence; in the first, the flowers open in the ACROPETAL or ascending order, in the second in the descending order.


Fig. 143. Spike.

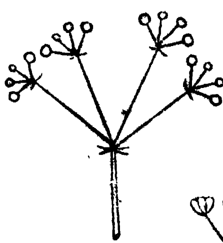


Fig. 144. Compound umbel.

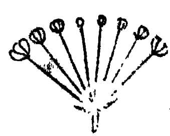


Fig. 145. Umbel.

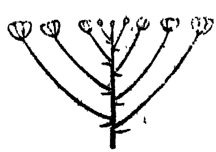


Fig. 146. Corymb.

Racemose or Indefinite inflorescences.—The simplest case is that of a long rachis bearing stalked flowers which open gradually from below upwards, so that the inflorescence is tapering. It is termed the RACEME. It is very common and may be observed in the Pea family, in the Mustard, the Radish, in the various kinds of Orchids, in the garden plants Delpinium, Antirrhinum, etc. A raceme with sessile flowers, that is, an elongated axis with

flowers seated directly on it, is called a SPIKE (fig. 143). It is found in the Bakash (*Adhatoda*) family, in all Grasses and cereals, as well as in all Palms. In the Aroids (Kachoo family), the spathe (p. 80) encloses a thick club-shaped rachis (fig. 139,s) on which there are hundreds of minute flowers (f). This is a modified form of the spike, and is termed the SPADIX; it is a fleshy spike. The inflorescence of the Banana (the flower-cone known as the Mocha) is also of the nature of a spadix (fig. 140). Sometimes a spike falls away from the parent plant when old, as in the Betel plant and the male Toddy-palm (Tal). Such a deciduous spike is termed a CATKIN. The flowers of a catkin do not produce fruits, for they are all male, and are as a rule minute, dry, scaly, and arise in large numbers.

The largest inflorescence (spike) is found amongst the Palms (fig. 134). The Fan-palm (*Corypha umbraculifera*), for instance, flowers only once in life, in 30 or 40 years, and then dies. The inflorescence consists of a huge cluster of spikes subtended by a large boat-shaped spathe. The small flowers are several lakhs in number. The almost similar though much smaller inflorescence of the Date-palm is well-known.

A peculiar form of spike is found in some of the garden varieties of the Cock's-comb (Morug-phul). The end of the vegetative shoot develops abnormally into a crest-like solid rachis (fig. 149), and this is covered on all sides with bright-coloured scales (bracts) and small, dry, sessile flowers. This inflorescence is sometimes called a **Caenanthium.**

The raceme and the spike are types of indefinite inflorescence with a long rachis. But the rachis is not elongated in all racemose inflorescences. In the Cauli-flower and in the Candytuft (*Iberis*), the inflorescence is more or less flat-topped. This is because the lower flowers are raised on longer stalks than the upper ones, so as to bring them all nearly on a level, as shown in fig. 146. The main axis is comparatively short. Such an inflorescence is termed a CORYMB. Another flat-topped inflorescence is the UMBEL (fig. 145), found in its simplest form in the Onion, Corian-

drum (Dhania), and Crinum (Sukhadarshan). Here the main axis is either very short or altogether undeveloped, so that the flower stalks all appear to spring from its tip. The inflorescence is so called because it looks like an open umbrella, as shown in fig. 145. In the Carrot and Anise family, the umbels are mostly compound; *i.e.*, the pedicels of the first set at the top of the rachis do not bear flowers but each supports a secondary set of radiating branches, forming secondary umbels or

Fig. 147. The Sensitive plant (Lujjabaty) —flowers clustered in a *Head*.

Fig. 148. Cyme of Phlox.

Fig. 149. The Cock's-comb.

UMBELLULES (fig. 144). Umbels usually have an involucre at their base. A compound raceme, such as is produced by the branching of a raceme, as shown in fig. 142, is often

termed a *panicle*; but the term is loosely applied to any form of branched raceme or corymb. A compound spike, as in Paddy and many grasses, is a raceme of spikes.

The inflorescence of the Sunflower family is termed the CAPITULUM (fig. 133). It consists of a bowl-shaped or flat rachis, as shown in section in fig. 137, and a large number of small sessile flowers seated on it. The whole cluster is surrounded on the outside by involucral bracts which serve to protect the young cluster. Gradually as the capitulum unfolds, the flowers at the circumference open out first, and then the inner ones circle after circle, and lastly those at the centre; that is, the flowers open *centripetally*, from the circumference to the centre. If we suppose the axis to be elongated, instead of being flat, the central flowers would be higher up the rachis, the outer flowers lower down, in regular order, and the opening of the flowers would be ascending or acropetal, as in a typical raceme. The flowers

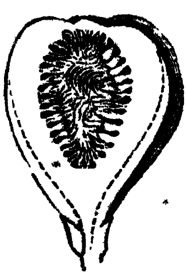


Fig. 150. The Fig.

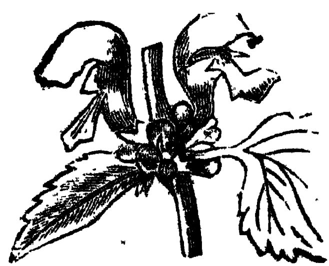


Fig. 151. A verticillaster.

at the circumference have each a spreading limb, and are called the RAY-FLORETS; the others are small and tubular, and are called the DISC-FLORETS. This is, however, not always the case. The capitulum of Kushum (*Carthamus tinctorius*), for instance, has flowers all alike.

A form of capitulum is the HEAD. In it the rachis forms a small ball with countless minute sessile flowers all over its surface. Examples are seen in the Kadamba (*Anthocephalous cadamba*), the Sensitive plant (fig. 147), the Babla (*Acacia*).

In an elongated racemose inflorescence the flowers open *acropetally*, *i.e.*, from below upwards. In a flat-topped racemose inflorescence, corymb, umbel, capitulum, they open *centripetally*, *i.e.*, from the outside to the centre. This is shown in figs. 145, 146. In a condensed cyme, however, the central flower opens first and then those that lie outside, *i.e.*, they open *centrifugally*, from the centre to the circumference. Hence the racemose is sometimes also called the centripetal, and the cymose the centrifugal type of inflorescence.

Cymose or Definite inflorescences.—The most distinctive feature of all cymose inflorescences is that the

Fig. 152. Helicoid cyme of Foxglove.

Fig. 153. A forked helicoid cyme.

main axis terminates in a flower, from below which the younger flowers are developed successively in a descending order. The simplest cyme may be observed in some of the Jasmines (Bel, Mallika, Shephalika), in the Karamcha (*Carissa Carandas*), etc. This *simple cyme*, shown in fig. 136, has only three flowers, the central older and two

younger lateral ones, so that it has the appearance of a three-pronged fork. More commonly, however, the lateral axes bear branches below their own terminal flower, and this arrangement is repeated in each of the branches, so that a complex and compact cymose inflorescence is the result (fig. 148). This may be observed in the Rangun (*Ixora coccinea*), *Spergularia*, etc. This inflorescence is termed a *dichasium*. In certain case, the main axis instead of producing only two lateral axes, as in the last case, throws out three or more branches, each of which may again branch in a like manner. Such a cyme is called a *polychasium*, but it is rather rare. Sometimes the flowers in a polychasium or dichasium are sessile. Such a condensed cyme forms a *fascicle*, as in the garden annual Sweet-william (*Dianthus barbatus*). When the fascicle is globose it is termed a *glomerule*.

In the Toolsy (Basil) family a peculiar form of condensed cyme is formed. The leaves are opposite, and each forms at its axil a three or five-flowered fascicle, so that the two fascicles together form a whorl of sessile flowers surrounding the stem. In each fascicle the central flower opens first (see fig. 151) and then those at the flanks. This inflorescence in known as the *verticillaster*.

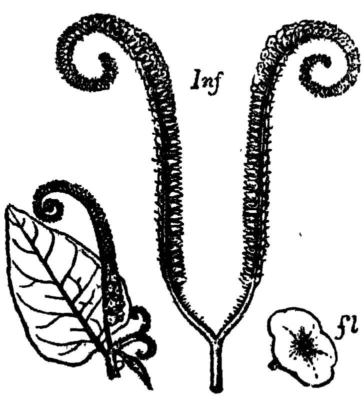


Fig. 154. Hatisoor.

Sympodial cymes.—If instead of two or more lateral branches, as in the above cases, the main axis forms only one branch below its flower, and this in its turn throws out a single branch below its terminal flower, and so on

the branches develop in this order, a one-sided or UNILATERAL cyme, or a monochasium is formed. This is shown in the diagrams (figs. 68 to 71) on p. 46.

Monochasial cymes have a sympodial axis, as explained on p. 46, and may be either HELICOID, or SCORPIOID in form. When simple they look like, and may be easily mistaken for a raceme, but the cymose nature is at once detected from the position of the flower-stalk which stand not in the axil of the bracts but opposite to them, as shown in figs. 69, 71. The inflorescence of the common fence-climber *Mina lobata* is a pair of helicoid cymes, as in fig. 153. Another example is Hati-soor, *Heliotropium indicum* (fig. 154).

Dichasial, polychasial, and monochasial cymes are also called *biparous, multiparous* and *uniparous* cymes respectively.

Mixed Inflorescence.—Various combinations of racemose and cymose inflorescences are met with. Thus, in the Sunflower, Zinnia, Chrysanthemums, etc., the individual capitula open centripetally, but they succeed one another on the primary stem in a descending order. The capitulum at the very top of the plant is the first to open, then the top branches from capitula at their ends, and then successively the lower branches. Similarly in the Toolsy family the verticillasters are cymes, but they develop and follow one another on the stem from below upwards, that is, racemosely. In the Teak (Shagoon—*Tectona grandis*) the flowers form a large much-branched inflorescence. The branches of the first and second order arise racemosely on the rachis, so that the form of the inflorescence is conical, but the terminal part of the branches bear simple dichasial cymes. The term *Thyrsus* has been applied to this sort of inflorescence.

The inflorescence of Figs (Doomoor) and Banyans is very complex. The flowers of these plants are extremely minute and lie hidden inside a bowl-shaped hollow rachis, as shown in fig. 150. The popular idea, that the Figs do not flower but at once form fruits, is explained by the fact that people do not see the flowers as they lie hidden inside the excavated rachis. They can be easily seen on cutting a longitudinal section of the young so-called fig-fruit. Such an inflorescence is termed a *Hypanthodium*.

SUMMARY.

A *Bract* is a leaf subtending a flower or a cluster of flowers. It usually protects the young flower-buds, but is sometimes coloured to attract insects, or may be dry and scaly. Kinds of bracts :—

1. *Foliaceous*, or small and green leaf-like bracts.

2. *Spathe*, a large bract sheathing a whole inflorescence, as in Palms, Aroids.

3. *Petaloid*, or highly coloured bract, as in Bougainvillea.

4. *Involucral bracts* form a whorl surrounding a dense flower-cluster, as in the Sunflower family, Carrot, etc.

5. *Paleæ*, or small, dry, scaly bracts subtending small flowers, as in the Sunflower and the Grasses.

An **Inflorescence**, or a flower-cluster, may be of the racemose or the cymose type. The following are the important forms.

I. Racemose or **indefinite inflorescence.** Main axis growing at top, not terminating in a flower.

A. Simple, or lateral axes unbranched.—

a. Main axis elongated, inflorescence conical.—

Flowers stalked, as in Mustard ... 1. RACEME.

Flowers sessile, as in Grass ... 2. SPIKE.

A fleshy succulent spike, (Aroids) ... 3. SPADIX.

A deciduous scaly spike, (Betel) ... 4. CATKIN.

b. Main axis short, inflorescence flat-topped.—

A flat raceme, as in Cauli-flower ... 5. CORYMB.

Flower-stalks radiating from tip of rachis, as in Coriandrum, Onion ... 6. UMBEL.

c. Main axis flattened, round, or hollow, flowers sessile.—

Form rounded like a ball, as in Babla 7. HEAD.

Form flat or concave, as in Sunflower ... 8. CAPITULUM.

B. Compound, or with lateral axes branched.

Main axis bearing racemes laterally ... 9. PANICLE.

Main axis bearing radiating umbellules, as in Carrot ... ... 10. COMPOUND UMBEL.

Main axis bearing spikes laterally (Grasses) ... ... 11. COMPOUND SPIKE.

II. Cymose or **definite inflorescence.** Main axis not growing at top, terminating in a flower,

A.	lateral axes more than two ...	1.	POLYCHASIUM.
	A condensed polychasial cyme ...	2.	FASCICLE.
	A rounded fascicle	3.	GLOMERULE.
B.	Lateral axes only two, as in Jasmines ...	4.	DICHASIUM.
	A pair of condensed dichasias in the axil of two opposite leaves ...	5.	VERTICILLASTER.
C.	Lateral axis only one on one side, main axis forming a sympodium	6.	MONOCHASIUM.
	The branches arise all on one side, so that the sympodium is coiled ...	7.	HELICOID CYME.
	The branches arise alternately on both sides of the sympodial axis ...	8.	SCORPIOID CYME.

QUESTIONS.

1. What are bracts? Where are they found? What is their function?

2. Explain: scape, peduncle, rachis, pedicel, involucre, spathe, paleæ. Give examples.

3. Give the distinguishing characters of a raceme, a spike, a spadix, and an umbel. Name plants which furnish examples of each of those.

4. What is an inflorescence? Name the principal types of inflorescence, illustrating your answer with sketches taken from common Indian plants.

5. Briefly describe, with examples, the following forms of inflorescence, and point out how one may be derived from the other: capitulum, corymb, catkin, umbel, panicle, dichasium.

6. Distinguish between the common forms of cymes, illustrating your answer with sketches.

7. Examine and describe the inflorescences of :—Sunflower, Cock's comb, Mustard, Kadamba, Kachoo, Palms, Teak, Carrot, Babla, Onion, Jasmines, Rangun, Crotons, Banana, and Betel plant.

8. Distinguish between centrifugal and centripetal inflorescence. Why are they so called? Give examples.

9. How would you distinguish (a) a helicoid from a scorpioid cyme, (b) a raceme from a helicoid cyme, (c) a head from a glomerule, (d) a corymb from an umbel? What is a mixed inflorescence?

10. What is a sympodial cyme and how would you distinguish it from a typical monopodial cyme? Illustrate your answer with examples and sketches.

CHAPTER VII.

THE FLOWER.

If we examine the flower of Lotus (fig. 155), we observe that the bud is covered on the outside by four green leaves which spread out gradually with the opening of the flower into four small boat-shaped bodies. These are termed the

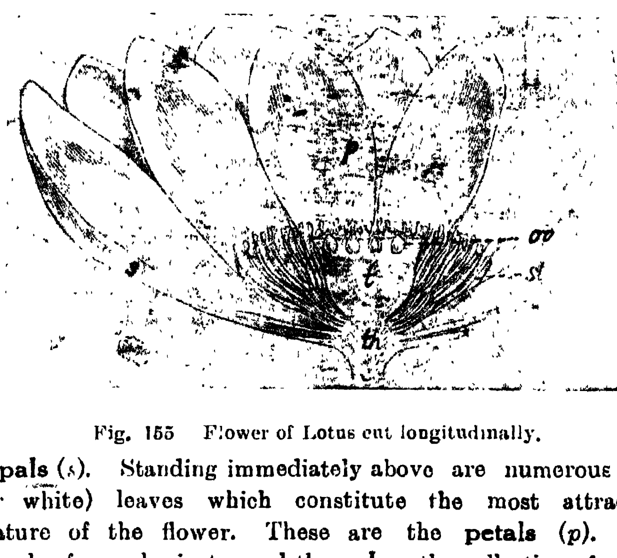


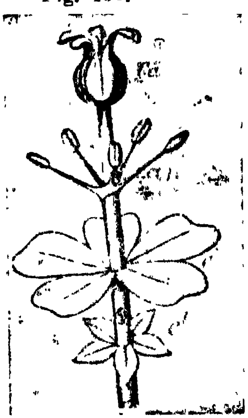
Fig. 155 Flower of Lotus cut longitudinally.

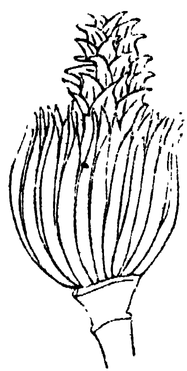
sepals (*s*). Standing immediately above are numerous red (or white) leaves which constitute the most attractive feature of the flower. These are the **petals** (*p*). The whorl of sepals is termed the **calyx**, the collection of petals the **corolla**. If we cut the flower vertically into two equal halves, we see that the peduncle is prolonged into it as a short stalk (*th*) from which the petals and sepals arise. This floral stem is termed the **thalamus**. Above the petals the thalamus bears a large number of short thread-like bodies, termed **stamens** (*st*), each tipped with a large

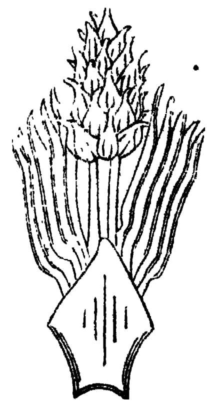
yellow portion, termed the anther. In a fully opened flower, the anthers are covered with yellow dust-like grains which readily stick to the finger when touched. These are the pollen-grains (phula-renu, puspa-parag). Above the stamens the thalamus is enlarged into a large top-shaped body (*t*), the flat top of which has several pits or chambers, each containing a small seed-like body (*ov*), or carpel.

Fig. 157. Fig. 158.

Fig. 156.







Flower of Champaka with petals removed. Fig. 157, the spires of stamens : at the top the carpels ; Fig. 158, vertical section of same.

Fig. 156 shows diagrammatically the structure of a typical Dicot flower. The thalamus is greatly elongated to show the four tiers of floral leaves ; the internodes between the whorls, as shown in the figure, are rarely found in a real flower. The first whorl *cl* is the calyx consisting of five sepals, the second *co* is the corolla consisting of five petals, the third *an* is the whorl of stamens called the andraecium, and the fourth *ca* is the whorl of carpels which is called the gynoecium.

The flower of the Champaka (*Michelia champaca*) shows the stamens and carpels better (figs. 157, 158). The thalamus here is elongated, and the floral organs are arranged spirally on it. There are no green sepals, but a large number of yellow petals which become smaller and smaller the higher they are on the thalamus. The stamens also are in spires, and so too the numerous carpels. Each carpel (see fig. 160 E) has a swollen basal portion, called the **ovary**, a short stalk above it, called the **style**, ending in a glistening tip, called the **stigma**. The ovary is a chamber within which are formed the **ovules**, or the rudiments of the seed.

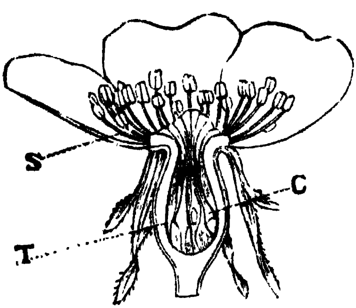
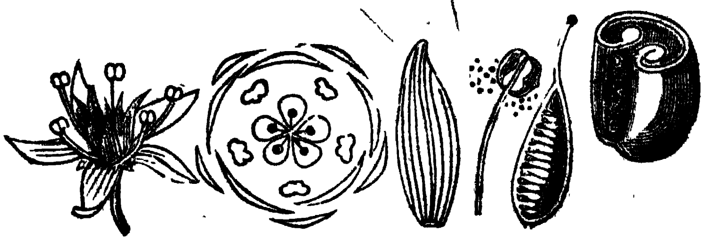


Fig. 159. Flower of Rose cut longitudinally.

The carpel is better seen in the Pea or the Bean flower. In Lotus the carpels are sunk in the thalamus, are very small, so that the ovary only is apparent. This is not, however, the case generally. The carpels are, as a rule, placed at the top of the thalamus. In Pea or Bean there is only *one* carpel, not several as in the last two cases. This can be observed, after first removing the calyx, the corolla, and the stamens, as a small, greenish, elongated body, seated at the middle of a flat thalamus. The lower part is inflated into a chamber (ovary), the upper slender portion is the style, and at its tip is the stigma. The ovary may be split open and the ovules may then be brought to view. When the ovary matures, it forms the well-known Pea-fruit (see fig. 57. L), the ovules in the meantime having developed into seed.

The thalamus is elongated, conical, or top-shaped in the Lotus and the Champaka, flat in the Pea. In the Rose it is hollow and bowl-shaped (T, fig. 159). The carpels (C) are concealed inside this, while from the rim or the margin of the opening arise the sepals, petals and stamens (S).

In a typical flower, then, we have four sets of organs, *viz.*, the sepals, the petals, the stamens, and the carpels. The sepals protect the young flower-bud, the petals attract insects when the flower is opened, insects come and take away the pollen-grains from the anthers and deposit them on the stigma. The stamens are regarded as the male organs of a flower, the carpels the female. The male substance is contained in the pollen-grains, the female element inside the ovules. When the pollen falls on the stigma, the two (male and female) elements unite, and the result is that the ovules are fertilised. In consequence they mature into



A B C D E F

Fig. 160. A, a typical Dicot flower with one whorl of stamens. B, floral diagram of same. C, a petal. D, a stamen with the anther at the top shedding pollen-grains. E, a carpel, the lower swollen part is the ovary inside which are the ovules; at the top of the ovary is the style and the round tip is the stigma. F, the ovary cut cross-wise to show the cavity.

seeds, and the ovary matures into the fruit. The following table gives a summary.—

1. *Thalamus*—the axis or stem of the flower, bearing
2. the *floral leaves*:—
   (a) the *calyx*, consisting of green covering leaves, or sepals;

(b) the *corolla* consisting of coloured leaves, or petals;

(c) the *andrœcium* consisting of the stamens; each stamen has
 i. a stalk, called *filament*, at the top of which is
 ii. a chamber, called *anther*, containing pol en-grains;

(d) the *gynœcium*, consisting of carpels; it has
 i. an *ovary*, a swollen chamber at the base,
 ii. a *style*, and
 iii. a *stigma*.

The stamens and carpels, the male and female organs, are also called the *essential organs* of a flower, for the main function of a flower is to produce seeds and this is not possible unless the two elements unite. The sepals and petals may be entirely absent, as in the minute flowers of the Kachoo (fig. 139, f. f], and so are regarded as non-essential.

The flower is a modified shoot.—The flower is a special kind of shoot. Its stem or axis is the thalamus which is generally not elongated, for the internodes are undeveloped. The floral members, sepals, petals, stamens and carpels, are special kinds of leaves, the last two greatly modified to produce certain bodies called *spores*, and hence they are also called *sporophylls* or spore-leaves. The sepals and petals are much less modified, and are known as *anthophylls*, or flower-leaves. The pollen-grains are the spores of the staminal leaf, and inside the ovule of the carpel-leaf is formed another kind of spore. A flower bud, like a foliage bud, often arises in the axil of a special leaf called bract. Thus the modified shoot, the flower,

(A) arises in the axil of bract leaves or *hypsophylls*, and

(B) consists of—

 1. an undeveloped stem, called *thalamus*, and
 2. floral leaves, of which

 i. the outer protective (calyx), and attractive (corolla) leaves are called *anthophylls*, and

 ii. the spore-leaves, or the stamens and carpels, are *sporophylls*. The above view of the morphological character of the flower is supported by the following facts:—

1. A flower bud, like a foliage bud, often arises in the axil of a leaf (bract).

2. Like foliage leaves, the floral leaves also open gradually from below upwards, or from the outside *i. e.*, acropetally; sepals open before petals, petals before stamens, and so on.

3. The floral leaves, especially sepals and petals, are arranged on the

thalamus much in the same plan as leaves are arranged on the stem (phyllotaxis). In some flowers, as in the Champaka (fig. 157), the floral leaves are in spires on the thalamus, *i.e.*, the arrangement is spiral, in others they are in whorls. But the whorls regularly alter-

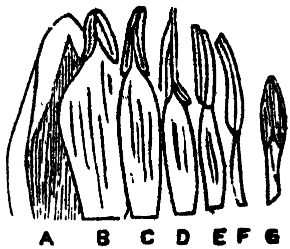


Fig. 161. Staminal leaves of Water-lily. A, a petal; B—G, stamens.

Fig. 162. A proliferous Pear.

nate; that is, petals stand in the intervals of sepals, stamens in the intervals of petals, and so on. Such alternation is also found in the case of foliage leaves (see p. 74).

4. In some flowers, as in the Water-lily, some of the stamens are flat and leaf-like, or rather, like petals. The outermost stamens (fig. 161 B) look like petals, gradually the inner ones (C—G) become smaller and smaller ending finally with the typical slender filament and large anther. The sepals and petals also exhibit a similar transition. The outer sepals are quite green, those inside are partly coloured, and then come the coloured petals. The inner petals become smaller and smaller and then pass into the stamens. This shows that they are all modified leaves.

5. In many cultivated flowers, the stamens and carpels are transformed into petal-like leaves. This is seen in what are called *double flowers e.g.*, double Rose, double Jasmine, double Java, double Sthalpadma (the changeable Rose—*Hibiscus mutabilis*), double Pink, etc In cultivation gardeners try to produce by artificial means large flowers with more numerous petals than in the natural flower. This

shows that under certain circumstances the stamens may revert to their fundamental character, *i.e.*, leaves.

6. Sometimes *prolifications*, or abnormal growths, occur in a flower. For instance, in some cultivated Datura we observe several corollas telescoped into a flower. This can be explained by supposing that floral leaves, like foliage leaves, are capable of producing axillary buds which may develop into flowers. Similarly a fruit inside a fruit has been seen in the Papaya, patol (*Trichosanthes diœca*), and other plants. Fig. 162 shows a shoot at the top of a fruit, formed by the proliferous elongation of the thalamus.

Monocot and **Dicot flowers** differ mainly in the number of floral leaves in each whorl. A TYPICAL Monocot flower has a whorl of three sepals, a whorl of three petals, two whorls each of three stamens, and a whorl of three carpels. There are five whorls each of three members, and so the flower is called TRIMEROUS PENTACYCLIC. Such a typical flower is however rarely met with, for the sepals and petals often unite to form a single whorl, and the andraecium also forms a single whorl of six stamens. This may be observed in the flowers of Onion, Crinum (Sookhadarshan), Lily, Gladiolous, etc. A typical Dicot flower has, on the contrary, five members in each whorl; *i.e.*, there are five sepals, five petals, two whorl each of five stamens, and a whorl of five carpels. A typical Dicot flower hence is PENTAMEROUS PENTACYCLIC, as shown in diagram (fig. 164). Such a typical flower is however rare, but may be seen in the garden shrub *Quassia amara*. A commoner instance is the flower of BRYOPHYLLUM (Pathur-kuchi) but the number in each whorl here is not five but four, the flower being thus TETRAMEROUS PENTACYCLIC. In many Dicot flowers the number of the floral members is very large, being as a rule multiples of five, as in Rose, Lotus, Water-Lily, Champak, etc.

Typical Dicot and Monocot flowers are said to be *diplo-stemonous*, *i.e.*, they have two whorls of stamens, the outer standing before the sepals and alternating with the petals, and the inner standing before the petals (fig. 163). In some cases this alternation is just in the

reverse way, and the flower is *obdiplo-stemonous* (fig. 164). In typical flowers the whorls of floral leaves regularly *alternate*: petals stand in the intervals of sepals, the outer stamens in the intervals of the petals, and so on. Flowers in which there is only one whorl of stamens (generally 5 in Dicots, 3 in Monocots) are termed *haplo-stemonous*.

Floral diagrams.—Ground-plans showing the relative arrangement of the parts of a flower are known as floral diagrams. They are very useful in the study of the flower, for they show in one view the relative position, number, etc., of the floral members. Fig. 163-65 are floral diagrams. The outermost circle is that for the sepals, next is for the petals, and so on. A *floral formula* gives a short expression for the numbers in a whorl. Denoting the calyx by C, the corolla by P, the andrœcium by St, and the gynœcium by G, the number of members is placed after the letters. Thus the floral formula of a typical Monocot flower is $C_3 \; P_3 \; St_3 + _3 \; G_3$; that of a typical Dicot is $C_5 \; P_5 \; St_5 + _5 \; G_5$.

Fig. 163.

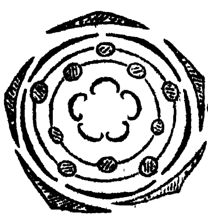
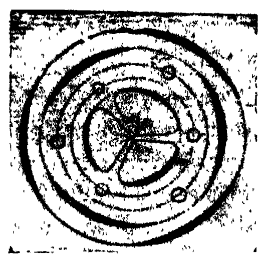


Fig. 164.

Fig. 165.



Floral diagrams of a pentamerous pentacyclic Dicot flower.

Floral diagram of a trimerous pentacyclic Monocot flower.

Cyclic and acyclic flowers.—In some flowers, *e.g.* Water-lily, Lotus, Champaka, etc., the floral leaves are arranged SPIRALLY on an elongated thalamus. Such flowers are termed ACYCLIC, as distinguished form CYCLIC flowers, *i.e.*, those in which the floral leaves are arranged in WHORLS or circles. Cyclic flowers are far more common, and have a lesser number of floral leaves than in acyclic flowers.

Regular and irregular flowers.—The members of a whorl are usually placed symmetrically round the thalamus, and this gives rise to the symmetrical appearance most flowers have. A regular or symmetrical flower is technically described as ACTINOMORPHIC. It can be cut into similar and equal halves by any plane passing longitudinally through the centre of the flower: Lotus, Rose, Java, Poppy are examples. Flowers in which the sepals and petals, especially the latter, are not all alike in size and shape, are called irregular—as in Pea, Bean, Banana, Balsam. Such flowers can, as a rule, be cut into two similar and equal halves, along only ONE plane, and are termed ZYGOMORPHIC flowers. Some flowers are however so irregular that they cannot be cut along ANY plane into two similar and equal halves; they have no plane of symmetry, and hence are called ASYMMETRICAL, *e.g.* Canna.

Complete and incomplete flowers.—In most flowers the calyx, the corolla, the stamens, and the carpels are present. Such flowers are said to be COMPLETE or PERFECT. But in many cases one or more of these organs may be absent, and the flower is INCOMPLETE or IMPERFECT—*e.g.*, in Cucumber, Papaya, Gourd, etc. Sometimes DOUBLING brings about the incomplete stage, *e.g.*, in the large Roses and double Java, where all, or almost all, the stamens and carpels are converted into petals. When both the essential organs are absent the flower is termed NEUTER. In the Kachoo family the minute flowers (fig. 139. f) have no calyx, nor a corolla, *i.e.*, they are NAKED.

Bisexual and unisexual flowers.—In a bisexual or HERMAPHRODITE flower stamens and carpels are both present; in a UNISEXUAL or DICLINOUS flower, one of these is suppressed. An unisexual flower is male or STAMINATE when only the stamens are present; female or PISTILLATE when only the carpels are present. Unisexual flowers

may be seen in the Cucumber, Gourd, Pumpkin, Papaya, Toddy-palm, Aroids, and so on.

Isomerous and anisomerous flowers.—Some flowers have equal number of members in the four whorls, *viz.*, calyx, corolla, andræcium, and gynœcium. Such flowers are termed ISOMEROUS (iso = same, equal). More commonly, however, suppression or multiplication takes place in the floral whorls, giving rise to an inequality in number. Thus, in the Java there are 5 sepals, 5 petals, 5 carpels, but numerous stamens; in the Mustard there are 4 sepals, 4 petals, but 6 stamens, and 2 carpels; in the Jasmines there are 5 sepals, 5 or more petals, but only 2 stamens and 2 carpels. Such flowers which are by far the most common are termed ANISOMEROUS.

QUESTIONS.

1. Describe the parts of a flower and the functions they perform. What are the essential organs and why are they so called?

2. Distinguish between a typical Dicot flower and a typical Monocot flower.

3. What are the reasons for holding that a flower is a modified shoot?

4. Explain with examples, and diagrams where possible: acyclic, zygomorphic, isomerous, unisexual, incomplete, cyclic, asymmetrical, staminate, pistillate, actinomorphic, and double flowers.

5. Examine the following flowers, describe their parts, and draw floral diagrams; Rose, Lotus, Water-lily, Champaka, Magnolia, Poppy.

CHAPTER VIII.

PARTS OF A FLOWER.

The thalamus is the axis of the flower; on it lie the floral organs. It is sometimes also called the TORUS or the RECEPTACLE. It may be elongated or conical, as in Champaka (fig. 158); flat or disc-shaped, as in Orange; concave or hollow, as in the Rose (Fig. 159). Its form determines the insertion of the floral members. Thus when it is elongated (Champaka), or but slightly convex or conical (Mustard), the floral whorls are arranged in order one above the other, the sepals forming the lowest and the carpels the topmost whorl, as shown in the diagram (fig. 166). Such a flower is termed HYPOGYNOUS. If, however, the thalamus is flat, concave, or cup-shaped, the gynœcium comes to lie in the centre, while the stamens are at the rim (figs. 167, 168), the flower is termed PERIGYNOUS, *e.g.*, the Rose (fig. 159). When

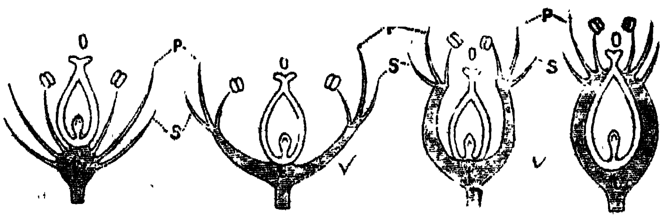


Fig. 166, Hypogynous. Figs. 167, 168, Perigynous. Fig. 169, Epigynous. The thalamus (t) is conical in fig. 166, cup-shaped in fig. 167, deep and urn-shaped in fig. 168, and hollow and closed at the mouth in fig. 169; o, the ovary with style and stigma is superior in the first three, inferior in the last, s, sepals; p, petals.

the concave floral axis becomes adherent to the gynœcium, as shown in the diagram (fig. 169), so that the other floral leaves appear inserted on the top of the ovary the flower is EPIGYNOUS.—*e.g.* Guava, Jambolan. In the last case the ovary is said to be INFERIOR; in the other two it is SUPERIOR.

In a hypogynous flower the thalamus is sometimes developed as a long stalk lifting one whorl of floral members above another. Thus, in the Lotus the thalamus is large, fleshy, and top-shaped at the end and has a number of carpels separately imbedded in it; such a thalamus is termed the GYNOPHORE. In orange the thalamus forms a small disc or cushion on which lies the ovary; this is termed the GYNOBASE. The elongated stalk interposed between the stamens and the corolla, as in *Gynandropsis pentaphylla* (Sada Hurhuria), is sometimes termed the ANDROPHORE; while the stalk lifting the corolla above the calyx, as in Pink, is the ANTHOPHORE. In some flowers, as in the *Gynandropsis* and the Kanakchampa (*Pteriospermum acerifolium*), the ovary is borne on a long stalk, and is hence described as STIPITATE.

The **perianth** is the term applied to the outer enveloping leaves (anthophylls, p. 96) of a flower. In the great majority of flowers it consist of two series, the calyx and the corolla. But in many Monocots, as in Rajanigandha, Onion, Crinum, Lily, Canna, Banana, etc., the calyx and the corolla cannot be distinguished, all sepals and petals being alike and forming a single series. To this the term perianth is applied. The leaves of a perianth is POLYPHYLLOUS (*poly*=many, free, *phyllome*=leaf); when united, it is GAMOPHYLLOUS (*gamo*=united). In Canna, Ginger, Onion, the perianth is polyphyllous; in Rajanigandha, Crinum, Banana, it is gamophyllous. In some Dicots the corolla is absent and the calyx alone forms the perianth. Thus in the Four o'clock plant (Krishnakali) the calyx forms a coloured gamophyllous perianth which looks like a corolla. In the Cock's-comb (Morugphul) the perianth consists only of five, dry, coloured scale-like sepals. The term PERIGONE is sometimes applied to a coloured corolla-like calyx.

A typical flower in which both the calyx and the corolla are present is described as dichlamydeous (di=two, chlamydon=coat). A

flower with only one series of perianth leaves, generally the calyx, as in Cocks'-comb, Four-o'clock plant, Natyashag (Amarantus), etc., is called monochlamydeous (mono=one). Flowers in which the perianth is entirely absent, so that only stamens or pistils constitute the flower, are described as naked or achlamydeous (a=not). For instance, the upper flowers (f) of the spadix of Kachoo (fig. 139) consist merely of stamens, and the lower flowers of only a single overy. Such naked flowers are also found in other plants of the Kachoo family, in the Betel plant, etc.

The calyx, the outermost whorl of floral leaves, serves mainly to protect the flower while it is in bud. Its leaves, termed sepals, are, as a rule, sessile, and may be either united or free. In the former case the calyx is called GAMOSEPALOUS; in the latter it is POLYSEPALOUS. The number of sepals in the calyx varies: *e.g.*, two in the Poppy (disepalous), three in the Custard-apple and in Monocots generally (trisepalous), four in the Mustard and Lotus (tetrasepalous), and five generally in Dicots. It usually falls away or shrivels up after the ovary is fertilised by the pollen but in many cases it persists and forms part of the fruit. A PERSISTENT calyx may simply form a thin bladder-like covering of the fruit, as

Fig. 170. Irregular flower of the Garden Nasturtium, C, the calyx with spur s.

Fig. 171. Ligulate ray-floret of a capitulum. CO, corolla; CA, calyx, ST, stamens with syngenesious anthers; OV, the inferior ovary.

in the Teak or the Cape-gooseberry (Tepari), when it is called ACCRESCENT, or may form the thick and fleshy portion of the fruit, as in DILLENIA (Chalta), when it is called MARCESCENT. A simple persistent calyx is seen in the Brinjal and in the Datura fruit. Ordinarily the calyx is DECIDUOUS like the corolla, but in Poppy it falls off as soon as the flower-bud opens, and then it is termed CADUCOUS.

Forms of calyx.—A calyx may be either regular or irregular. A regular calyx may be TUBULAR or like a tube, CAMPANULATE or bell-shaped. An irregular calyx may be BILABIATE (two lipped), SPURRED (fig. 170) or provided with a long pouch or beak-like process (Balsams); GALEATE or hooded and arching, (Aconite). In some capitula the flowers have a dissected calyx, there being a tuft of long hair-like segments on the top of the ovary (A, figs. 176, 178). These are best seen in old capitula where the flowers have withered and small fruits are formed. The whorl of hairy segments representing the calyx is termed the PAPPUS, the calyx itself being termed PAPPOSE.

Fig. 172.

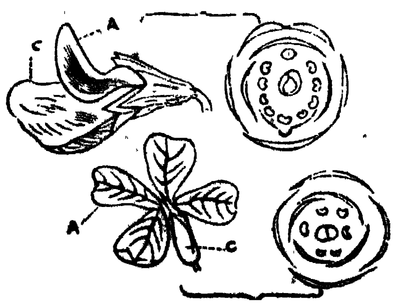


Fig 173.

Fig. 172. Papilionaceous flower; to the right the floral diagram. A, the vexillum; C, the alæ or wings.

Fig. 173. Cruciform flower; to the right the floral diagram. A, the corolla of four petals arranged in the form of a cross; C, the calyx.

Sepals are, as a rule, sessile and exstipulate, but in the Rose family the stipules of the sepals form a whorl below the calyx. This is called the EPICALYX. In the Java

and Cotton family there is a whorl of green bracts just below the calyx; this is also called the epicalyx.

The corolla, consisting of the petals, is the most attractive and delicate part of the flower. It is, as a rule, cast off immediately after fertilization. It may be POLYPETALOUS, with petals free or GAMOPETALOUS, with petals united. It is regular or irregular, according as the petals are all alike in form and size or not. It exhibits a great variety in shape and form, all of which are devices for inviting different insects to the flower. Sometimes its bright colour alone serves the purpose, sometimes a sweet scent is emitted, and often sweet liquid or honey is secreted at its bottom. In some flowers a special sac (fig. 170,S, fig. 175,C,) called NECTARY, is formed for collecting the honey or NECTAR which is an additional attraction to the insect. The object of the insect-visit is to carry the pollen from one flower and deposit it on the stigma of another flower. This is called POLLINATION. The main function of the corolla is to bring about pollination.

Petals are, as a rule, sessile, but in some cases they are stalked. This may be seen in the flowers of the Jarul tree

Fig. 174. Fig. 175. Fig. 176. Fig. 177. Fig. 178. Fig. 179.

Fig. 174. Bilabiate corolla with lips B, B; A, the calyx.
Fig. 175. Personate corolla—throat closed; C, spur; A the calyx:
Fig. 176. Ligulate corolla—A, the pappose calyx.
Fig. 177. Campanulate corolla C; A, the calyx.
Fig. 178. Disc-floret of a capitulum; B, the tubular corolla; A, the pappus. Fig. 179. Urceolate corolla B; A, the calyx.

(*Lagerstræmia Flos-reginæ*), the Henna (Menthy—*Lawsonia Innermis*), the Pink, etc. The stalk is called the UNGUIS, and the stalked petal is called UNGUICULATE. In the Passion-flower the corolla bears a circle of hairy outgrowths from its surface which renders it highly attractive. Such an outgrowth is called a CORONA.

Forms of polypetalous corolla—

I. REGULAR.—

1. *Cruciform* or *cruciate*; a corolla of four petals with a short stalk and limbs spreading in the form of a cross. Ex. Mustard, Radish. Fig. 173.

2. *Rosaceous*: a corolla with five roundish and spreading petals, as in the Rose.

3. *Caryophyllaceous*: a corolla with five long-stalked petals which spread out their lobes above and are enclosed below within a calyx tube. Ex. pink.

4. *Liliaceous*: a perianth of six leaves so formed as to look like a narrow funnel. Ex. Lily.

II. IRREGULAR.—

5. *Papilionaceous*: it is the peculiar butterfly-like corolla of the Pea family. It consists of five petals: one large, termed the vexillum or standard (fig. 172 A), which overarches two lateral petals, which in turn partly overlap two lower petals fused to form a small boat-shaped structure. This latter is called the *keel* or *carina*, and encloses the stamens and the carpel; the two lateral petals (C) are known as the *alæ* or *wings*.

Forms of Gamopetalous corolla.—

I. REGULAR.—

1. *Tubular*: a tube-like corolla. Ex. Rangun (fig. 180).

2. *Rotate*: a corolla without any tube but spreading widely from the very base. Ex. Brinjal, Potato.

3. *Campanulate* or bell-shaped: a corolla rounded at the base and gradually expanding so as to look like a bell (fig. 177).

4. *Infundibuliform* or funnel-shaped, as in Datura, Tobacco.

5. *Hypocrateriform* or salver-shaped: a corolla with a long narrow tube and five lobes spread out like a saucer. Ex. *Vinca* (Nayantara), the Jasmines.

6. *Urceolate*: a corolla swollen at the middle, narrow at the base, and contracted at the mouth, as in *Vaccinum* (fig. 179).

II. IRREGULAR—

1. *Ligulate* or *strap-shaped*: a corolla tubular and narrow at the base and spread out quite flat at the top. The tube appears to split open at one side and spreads out a long tongue. It looks like a single petal but there are notches at the tip of the flat limb indicating the gamopetalous character. Ex. the ray-florets of Sunflowers, Zinnia, etc. Fig. 176.

2. *Labiate* or *bilabiate*: an irregular corolla with two lips. Ex. Toolsy (the Basil); Bakash (*Adhatoda vasica*). The upper and lower lips are notched, indicating the number of petals they are made up of. Fig. 174.

3. *Ringent*: a bilabiate corolla with two gaping lips.

4. *Personate*: a bilabiate corolla with the throat or opening closed by a projection of the lower lip. Ex. Antirrhinum, Torenia. Fig 175.

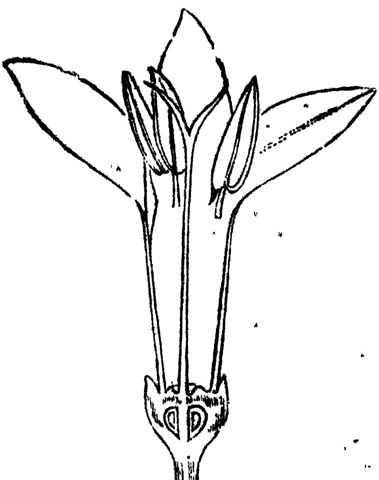


Fig. 180. Epigynous flower of Rangun (*Ixora*), cut vertically; the ovary inferior, the tubular corolla superior.

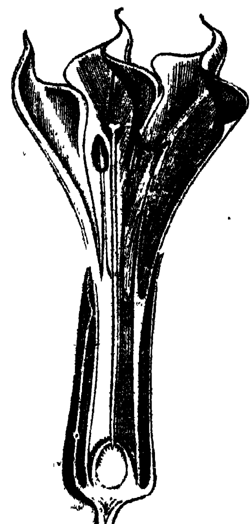


Fig 181. Flower of Datura cut vertically, showing the plaited corolla.

Aestivation, or the manner in which the floral leaves (sepals and petals) are relatively arranged in the bud, is called :—

1. VALVATE, when the margins of the sepals or petals merely touch and do not overlap, as in the calyx of Cotton and Java, the petals of Akanda (the Madar—*Calotropis gigantea*).

2. IMBRICATE, when the margins overlap, as in the corolla of Rose. The term is loosely used for any sort of overlapping.

3. CONTORTED, CONVOLUTE or TWISTED, when each sepal or petal is overlapped on one side and itself overlaps another by the other side, so that the whorl (calyx or corolla) seems twisted. Ex. the petals of Java, Cotton.

4. PLAITED, when each petal or corolla-lobe (of a gamopetalous corolla) is folded along the median, like a note-paper. This may be seen in Datura (fig. 181), Morning-glory and *Ipomoeas*, where the plaited corolla-lobes are convoluted, so that the corolla is twisted. The aestivation is hence called PLAITED CONVOLUTE.

Fig. 182. Vexillary aestivation of the flower-bud of Pea. C, the calyx; v, the vexillum; W, the two wings; K, the karina or keel.

5. VEXILLARY, in papilionaceous flowers, as shown in fig 182. The large STANDARD or VEXILLUM almost covers the other petals; the WINGS overlap or completely cover the small keel or karina.

QUESTIONS.

1. Describe with diagrams the structure of a hypogynous, a perigynous, and an epigynous flower. Give examples.

2. What are the following and where do you find them? anothophore, gynobase, perigone, pappus, epicalyx, corona, androphore, nectary.

3. What is the function of the calyx? Give examples of cases where the calyx persists and forms a part of the fruit.

4. Examine the following flowers, and describe their calyx and corolla with reference to (A) form (B) insertion, (C) aestivation:—Balsam, Rose, Sunflower, Pea, Potato, Datura, Jasmine, Water-lily, Poppy, Mustard, Cucumber.

5. Name the various forms of gamopetalous corolla. Give examples.

6. Describe the various ways in which floral leaves are disposed in the bud.

CHAPTER IX

THE ESSENTIAL ORGANS.

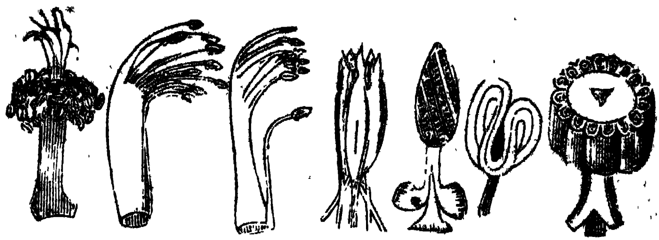
When the stamens and the carpels are both present the flower is *bisexual, hermaphrodite* or *monoclinous.* When either is absent the flower is *unisexual* or *diclinous.* If staminate and pistillate flowers are borne on the same individual plant it is *monœcious* (*mon*=one, *œkos*=house, in the same house or plant), *e.g.*, Cucumber, Gourd, Melon, etc. If they are on different individuals, so that one plant bears only the male (staminate) flowers and another only the female (pistillate), the plant is *diœcious* (*di*=two), *e.g.*, Papaw, Toddy-palm (Tal), Patol (*Trichosanthes dioica*). Flowers are said to be *polygamous* when male, female, and hermaphrodite flowers are all borne on the same plant *e.g.*, Mango.

The andrœcium, or the whorl of stamens, stands below, around, or above the ovary according as the flower is hypogynous, perigynous or epigynous (see p. 102). The term is derived from Gr. *andria*=man, the stamens being the male organs of a flower. A flower is *monandrous,* when it has only one stamen (Canna), *diandrous,* when two (Jasmines), *triandrous,* when three (Wheat), *tetrandrous,* when four (Rangun), *pentandrous,* when five (Brinjal), *hexandrous,* when six (Rice), *heptandrous,* when seven (Asoka —*Saraca indica*) *octandrous,* when eight (Henna—*Lawsonia innermis*), *enneandrous* when nine (Tejpata—*Laurus malabaricum*), *decandrous* when ten (Neem), *do-decandrous* when twelve (Dhau—*Woodfordia floribunda*), and *polyandrous* when it has numerous stamens (Rose).

When the number of stamens is equal to or some multiple of the number of petals, the flower is *isostemonous*; when the number is different, usually less than the petals, as in irregular gamopetalous flowers, it is *anisostemonous.*

A stamen has two principal parts ; the stalk or *filament* and the chamber called *anther*. The two is connected by a prolongation of the filament called the *connective*. In some flowers all

Fig. 183. Fig. 184. Fig. 185. Fig. 186. Figs. 187, 188, 189.



Figs. 183, 184. Monadelphous stamens. Fig. 185. Diadelphous stamens of Pea. Fig. 186. Syngenesious anthers of five stamens. Fig. 187. same of three stamens. Fig. 188. A single sinuous anther of Gourd. Fig. 189. Cross section of the syngenesious stamens of Gourd.

or some of the stamens are *sterile*, *i.e.*, they have no anthers; consequently they have no male function. Such sterile stamens are called *staminodes*. Stamens are described as.—

1. DIDYNAMOUS : when there are four stamens in two pairs, one pair shorter than the other (fig. 204) —*e.g.*, Toolsy, Til (*Sesamum*).

2. TETRADYNAMOUS : when there are six stamens of which four are long and the other two short, as shown in fig. 205—*e.g.*, Mustard, Radish.

3. MONADELPHOUS : when the filaments cohere to form a single bundle or tube (round the pistil when present), while the anthers are free, as shown in figs. 183, 184,—*e.g.*, Cotton, Java.

4. DIADELPHOUS : when the filaments unite to form two distinct bundles, as in Pea, where of ten stamens nine form a single bundle, and the tenth is free (fig. 185). So we may have *triadelphous*, *pentadelphous*, (Silk cotton —Simul) etc., stamens.

5. SYNGENESIOUS : when the anthers of a whorl of

stamens cohere to form a tube (surrounding the style when present) while the filaments are free (figs. 186, 187,)—*e.g.*, Sunflower, Zinnia, Marigold, Gourd, etc.

6. GYNANDROUS: when the stamens are borne upon the pistil, as in Orchids.

The filament is, as a rule, very slender and thread-like. But in some cases it is expanded or flattened, as in the Water-lilies and Canna. In the latter it is like a petal with a small yellow anther at one margin. Such a stamen is described as PETALOID.

The anther, commonly regarded as the blade of the staminal leaf, may be imagined to be formed by the

Fig. 190. Fig. 191. Figs. 192, 193, 194, 195, 196.

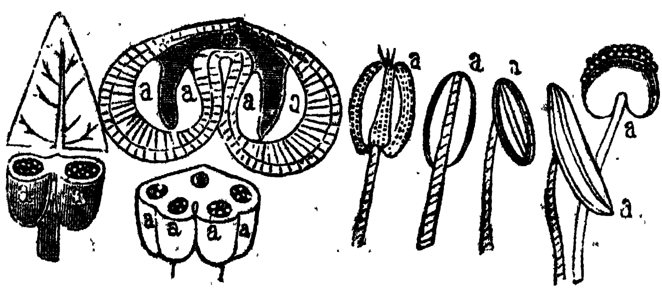


Fig. 190. A staminal leaf showing formation of anther a; fig. 191. the same showing the formation of a 4-celled anther, a; Fig. 192, innate; figs. 193, 194, adnate or dorsifixed; fig. 195, versatile anther (a). Fig 196. Unilocular anther (a) dehiscing transversely

infolding of the margins of a leaf towards the midrib, as shown in fig. 190, a. In this way we get the typical *two celled* anther with the midrib as the connective. The chambers, called pollen-sacs, are in their early stages divided into two by a partition wall stretching from the connective to the other side, as shown in fig. 191. The young anther is thus four-celled, but as it ripens the partition walls break off and it becomes two-celled. In Cotton, Java, and other plants of the family the anther is only one-celled (fig. 196). A peculiar form of anther

is seen in the Cucumber family where it is long, sinuous, folded and one-celled (figs. 188, 189). When mature the anther bursts and discharges the pollen-grains.

The modes of **dehiscence of the anther** are :—

1. *Longitudinal, i.e.*, the anther-sacs burst along vertical lines, usually two running the whole length from top to bottom. This is most common.

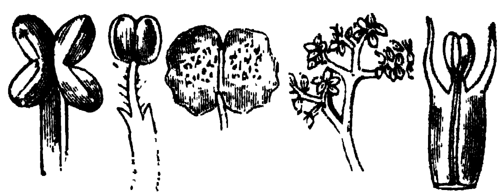
2. *Transverse, i.e.*, along a transverse line, as in the Cotton family (fig. 196).

3. *Porous, i.e.*, through small openings or pores formed usually at the top of the anthers, as in Potato, Brinjal.

4. *Valvular, i.e.*, through small valves which open out like windows in dry weather and flap down and close the opening in moist weather, as in Cinnamon (Dalchini)—fig. 206.

The **attachment** of the anther to the filament is called.—(1) *adnate* or *dorsifixed*, when the filament is attached to the back of the anther so that it is immovable; (2) *innate* or *basifixed*, when the anther is at the top of the filament so that the anther-lobes stand on two sides of the connective; and (3) *versatile*, when it is attached at only one point so as to swing freely from the tip of the filament. When the anther faces the centre of the flower, it is said to be *introrse*; when it faces the petals, it is *extrorse*.

Fig. 197. Fig. 198. Fig. 199. Fig. 200. Fig. 201.



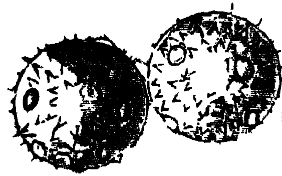
Different kinds of anthers and filaments.

Fig. 197. Anthers of *Cacao*. Fig. 198. Stamen of *Aconite*. Fig. 199. Anther of *Mirabilis* (Krishnakali). Fig. 200. Branched stamen of *Ricinus* (castor oil) Fig. 201. Flat stamen of Onion (*Allium*) with appendages.

Pollen-grains are usually granular, and may be dry or sticky. They vary much in size, form and colour. Some are shown in figs. 202-3. In certain plants, *e.g.*, the Orchids and in plants of the Akanda (*Calotropis gigantea*) family, all the grains of an anther-sac are aggregated into a single mass called a *pollinium*.

A pollen grain has usually two coats: an outer protective coat, called the *extine*, which has peculiar outgrowths such as spines, ridges, etc., and an inner thin wall, called the *intine*. When the pollen falls upon a suitable stigma the intine swells and comes out through the thinner parts of the extine as a tube, called the *pollen-tube* (fig. 215). The grains of the Cotton, Java, and Cucumber (fig. 202) are very large and may be seen with advantage under a microscope. Pollen-grains are easily destroyed by moisture. This may be observed under the microscope by placing a drop of water on dry pollen gathered from an old flower; soon the grains burst and discharge a frothy matter.

Fig. 202.



Pollen of Cucumber.

Fig. 203.

Various forms of pollen-grains.

The **gynœcium** or **pistil** may consist of one or more carpels. It may be *monocarpellary*, *dicarpellary*, *tricarpellary*, *tetracarpellary*, and so on, according as the number of carpels is one, two, three, four, and so forth; it is *polycarpellary*, when there are many carpels. It may be either *simple*, when the carpels are separate and free, or *compound*, when the carpels are united together. In the first the gynœcium is *apocarpous*, in the second it is *syncarpous*. The essential parts of a gynœcium are the ovary and the stigma. The style is usually present, but it may be absent so that the stigma is *sessile*, as in Poppy, Chalta (*Dillenia*), Water-lily.

The carpel or the carpellary leaf must be supposed to be

folded on itself so that the margins meet, as shown diagrammatically in figs. 207, 209, 211. The closed chamber so formed is the ovary; the prolongation of the tip of the leaf is the style, and the apex develops the stigma. In a monocarpellary gynœcium, as in the Pea family (Pea, Bean, Pulses, Acacia, Tamarind, etc.,) there is only a single carpel folded as described above.

Fig. 204. Fig. 205. Fig. 206. Figs. 207, 208, 209.

Fig 204. Didynamous, fig. 205. tetradynamous stamens. Fig. 206. Valvular dehiscence of anther of Cinnamon. Fig. 207. A carpel leaf forming the ovary. Figs. 208 and 209, the ovary cut open to show the placenta.

Apocarpous gynœcium—When there are several carpels in a flower and they are all free and separate, so that each carpel has its own ovary, style, and stigma, the pistil is called apocarpous. Thus in Champaka and Magnolias there are numerous carpels in one flower, and they are arranged spirally on an elongated thalamus. In Rose the hollow urn-shaped thalamus contains a few separate carpels. In Lotus the top-shaped thalamus has several small carpels separately imbedded in it.

Syncarpous gynœcium—results from the union of the carpels of a flower; it has usually a single ovary but the styles and stigmas may or may not unite (fig. 210). Where the union is complete, the pistil has a single ovary, a single style, and a single stigma; where partial, it may have a

single ovary with separate styles and stigmas, or a single style and stigma and separate ovaries. Thus in Palms the pistil is composed of three carpels but they are united to produce one ovary, one style, and one stigma. In cotton, Java, and other plants of the family there are five carpels united to form a single syncarpous ovary but the style at the top has five or more segments, each bearing a stigma. In Akanda (*Calotropis gigantea*), Nayantara (*Vinca rosea*), Karabi (*Nerium odorum*), and other plants of the family, the stigmas are united but the two carpels form two separate ovaries.

The **placenta** is the tissue in the interior of the ovary on which the ovules are borne. It is usually developed inside the ovary on the united margins of the carpel-leaf (see figs. 209, 212). Where a single carpel forms the ovary, as in the Pea family and in apocarpous pistils, the two united margins of the carpel-leaf usually bear two rows of ovules, i.e., the placenta is double, one belonging to each margin (fig.209). This may be easily seen by splitting an unripe Pea fruit. The placenta here is in the margin, or *marginal*. The part of the carpel bearing the placenta, i.e, the united margins, is

Fig. 210. Fig. 211.

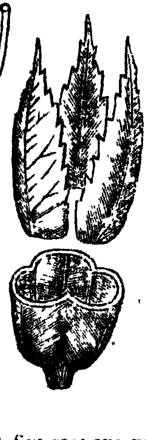
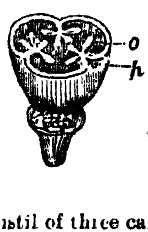


Fig. 212. Fig. 213.



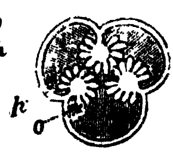


Fig. 210. A Syncarpous pistil of three carpels, styles free.
Fig. 211. Carpel leaves forming a syncarpous pistil.
Fig. 212. Unilocular ovary ; p, placenta, o, ovules.
Fig. 213. Same in cross-section.

called the *inner* or *ventral suture*; while the outer or *dorsal suture* corresponds to the midrib of the folded carpel.

The simplest case of a syncarpous ovary is where the margins of the contiguous carpel-leaves unite as shown in fig. 211, so that a *uni-locular* or *one-celled* ovary is formed. The placentas develop where the union takes place and their number generally indicates the number of carpels which make up the syncarpous ovary. The placentas are here *parietal, i.e.* on the wall of the ovary. This may be seen in the ovary and fruit of the Papaw, Pumpkin, Musk-melon (Kharbooj), Passion-flower etc. The placentas in these instances are vertical ridges on the inner wall of the ovary, corresponding to the contiguous margins of the carpel-leaves. In some cases the whole inner surface of the ovary develops as a placenta bearing numerous ovules, *e g.*, Pansy, Water-lily.

In other syncarpous pistils the ovary is divided into chambers or *cells,* and it may be two-celled, three-celled, four-celled and so on, according to the number of carpels, each carpel corresponding to a single cell. The marginal portions of the carpel-leaves folded inwards meet in the axis, and the placentas unite so as to form a single *central* column. This is shown in fig. 210. The placentas here are *central* or *axile.* The partitions dividing the ovary into cells consist of the united contiguous portions of the walls of the carpels, and are called *dissepiments.* These are necessarily composed of two layers which often separate in the ripe fruit to scatter the seeds. The ovary or the fruit of the Red-pepper (Lanka) is two-celled with an axile placenta bearing numerous seeds in each cell; that of Canna, Palms, and the garden Lilies, is three-celled; that of plants of the Cotton family is often five-celled, and so on. Sometimes a *false dissepiment* stretches from the dorsal suture to the centre of each carpel, dividing the cell into two.

In the Pink (*Dianthus*) and some other flowers, the ovules

arise on a central column which springs from the base of the ovary as a peg-shaped projection but is not attached to the walls. The placentation is said to be *free central*. An extremely simplified case is where the ovule arises from the very base of the ovary; that is, where the placenta is *basal* as in the Sun-flower family. The following is a summary—

Placentation, or the mode of distribution of placentas.

1. *Marginal*, as in apocarpous ovary, *e.g.* Pea.
2. *Axile*, as in syncarpous 2 or more celled ovary, *e.g.* Java.
3. *Parietal*, as in syncarpous one-celled ovary—*e.g.* Papaw.
4. *Free-central*, as in one-celled syncarpous ovary with a free columnar placenta from the base of the ovary, *e.g.* Pink.
5. *Basal*, one ovule arises at the base of ovary, *e.g.* Sunflower.

The **style** proceeds from the top of the ovary and is traversed by a narrow canal which leads to the chamber of the ovary. The inner surface of this canal develops when mature a tissue which ends in the placenta below and the stigma at the top. The pollen-tube formed on the germination of the pollen grain on the stigma passes through this tissue. As a rule the style is at the top of the ovary, *i.e.*, it is *terminal*. Sometimes it is displaced on the side of the ovary, and is then *lateral*; when the displacement is greater, the style may arise from the base of the ovary, *i.e.*, it is *basal*. In the Toolsy family it appears as if the ovary were depressed in the centre, and the style rising from the depression in the midst of carpels seems to come from the thalamus; such a style is termed *gynobasic*.

The **stigma** is the termination of the style. It consists of a loose tissue, and secretes a viscid matter which detains the pollen and causes it to germinate. This secreting tissue is the true stigma, but it is more commonly distinguished as the *receptive spot*, while the divisions of the style on which the receptive spot is developed are called the **stigma**. The divisions of the stigma often mark the number of carpels which compose the pistil: thus, in Java the *five-fid* stigma

indicates five carpels, in Rangun and Sunflower the *two-fid* or *bifid* stigma indicates two carpels, in Cucumber the *trifid* stigma indicates three carpels, and so on. Sometimes, as in Grasses and cereals, the stigma of a single carpel becomes *feathery* or *dissected*. A simple rounded stigma is called *capitate*.

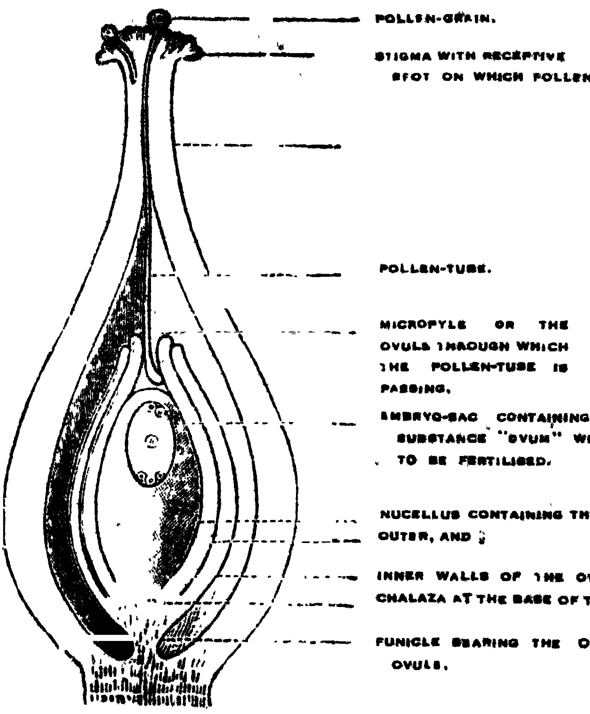


Fig. 215. Pollen-tube from a pollen.

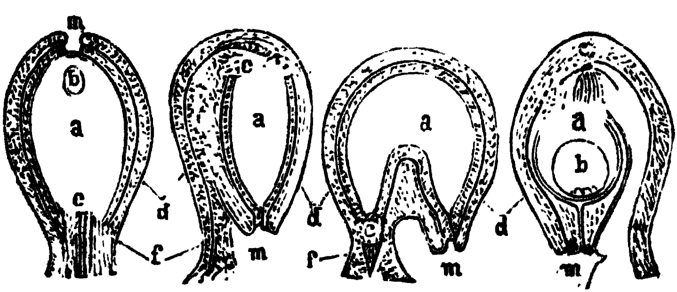
Fig. 214. The process of fertilisation and the structure of the ovule —diagrammatic.

The ovule arises from the placenta as a small, bud-like, conical bulging which soon grows up into an oval or elliptical body, often supported on a stalk called the FUNICLE or FUNICULUS (fig. 214). The body of the ovule, called the

NUCELLUS, is protected by one or two coats which gradually grow up from its base and cover the nucellus, leaving an opening at the top, called the MICROPYLE or FORAMEN. The base of the nucellus, where the coats arise, is called the CHALAZA. The point where the body of the ovule is attached to its stalk (funicle) and afterwards breaks away from it when the seed is ripened, is called the HILUM; in the seed this is marked by a scar. Inside the nucellus, towards the micropylar end, is formed a minute chamber, called the EMBRYO-SAC containing the female substance (OVUM) of the plant. The pollen-tube carrying the male substance passes through the micropyle, pierces the nucellus and the embryo-sac, and then the two male and female elements unite. The ovum thus fertilized then gradually develops into the embryo.

Forms of ovule.—1. The typical ovule, shown in figs. 214, 216 is the STRAIGHT, ATROPOUS or ORTHOTROPOUS

Fim. 216. Fig. 217. Fig. 218. Fig. 219.



Orthotropous, Anatropous, Campylotropous ovules. Anatropous ovule of Lily showing a, nucellus; b, embryo-sac; c, chalaza; d, integuments; f, funicle; m, micropyle.

ovule. Here the chalaza and the hilum lie close together, the micropyle lies at the other end, so that beginning from the placenta we have: the funicle, the chalaza,

the two coats, the nucellus, and the micropyle. This is not very common but may be seen in the Cubeb, Black-pepper, Betel, and a few other plants.

2. ANATROPOUS, or INVERTED ovule, is far more common. Here the funicle pushes up the base of the nucellus until it is inverted, and forms a ridge to it as shown in fig. 217. The mycropyle points to the placenta, the chalaza is at the opposite end, and the hilum (when the seed breaks away) near the micropyle.

3. CAMPYLOTROPOUS, or CURVED ovule, has its nucellus curved or bent like the letter U, as shown in fig. 218, so that the chalaza, the hilum, and the mycropyle, all lie close together. Ex. many Grasses.

4. AMPHITROPOUS ovule has its body set at right-angles to the funicle. The body of the ovule is straight, so that the micropyle, nucellus, and the chalaza are all in one line, but it is so twisted that the long axis is at right angles to the funicle. Ex. Poppy.

QUESTIONS.

1. Explain the terms : monadelphous, syngenesious, tetradynamous stamens, and diclinous, monoclinous, diœcious, and monœcious flowers. Give examples.

2. What are : staminodes, pollinia, petaloid stamens, versatile anthers, apocarpous and syncarpous pistils ? Give examples.

3. Give with examples the various ways in which (*a*) anthers dehisce, (*b*) anthers are attached to the filament, (*c*) placentas are developed in the ovary.

4. What is an ovule ? Describe with diagrams its structure and function.

5. Describe with examples the various forms of the ovule. Give sketches.

6. What are the following and where do you find them ?—extine, pollen-tube, chalaza, polygamous flowers, foramen, monocarpellary ovary, compound pistil, intine, hilum, free-central placenta, embryo-sac, gynobasic style, receptive spot, and unilocular anther.

CHAPTER X.

POLLINATION.

Pollination, or the transference of the pollen from the anther to the stigma, is the first important function of the flower. The pollen-grains cannot themselves reach the stigma, for often the stamens are of a different length than the style, so that the anthers are at a higher or lower level, and some flowers are unisexual. The pollen-grains must be carried from the anther to the stigma. This conveyance is secured with the help of (*a*) wind, (*b*) insects, (*c*) birds, or (*d*) other animals, and sometimes of (*e*) water. Various contrivances are found in flowers, to secure the help of one or other of these agents for pollination.

Anemophilous or *wind-pollinated* flowers are very small, dry, and inconspicuous. They are neither showy, nor fragrant, for the perianth is minute and scaly, and no honey is secreted. Examples are the Grasses, cereals, Bamboos, many Palms, and the Mulberry tree. The flowers are often clustered in spikes or catkins so that they swing freely in the air. Pollen-grains are produced in enormous quantities in large capacious anthers which dangle in the air at the tip of long thread-like filaments, so that the pollen is easily blown away by the wind. This is seen very clearly in all grasses and cereals. In other cases the anther bursts suddenly and the pollen is ejected with force. As pollen is spoilt by moisture, the anthers open only when a light dry wind is blowing, and not when the air is damp or stormy. The pollen-grains are small, light, and dry, and do not stick to one another, so that they are easily shaken off the anther. They have a smooth rounded surface, so that if arrested by the leaves they at

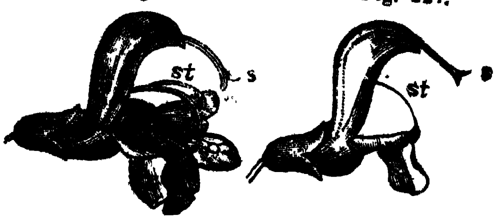
once roll off and float away in the air. In some cases (Pines) they are provided with wing-like appendages which help them to be carried over a long distance. The stigma is also well-adapted to catch the flying pollen. It is very large, often brush-like, feathery or dissected, as in grasses and cereals, so that a large surface is exposed, and the pollen borne by the wind is caught as if in a net.

Anemophilous flowers are often unisexual; either diœcious or monœcious. For instance, the male Toddy-palm (Tal) bears a long thick spike of countless minute staminate flowers alone; the pollen is carried by the wind to the female fruit-bearing trees; so too in the Date (*Phœnix*) tree, and in the Ketuky (Kea—fig. 32 shows the female plant), the sweet-scented male inflorescence of which is largely used in the country for flavouring catechu. The Castor-oil plant is another instance of anemophilie; the male flowers have much-branched stamens and countless anthers, the female have large branched feathery stigmas, both flowers being on the same plant. Other instances are the Jack, the Mulberry, some Crotons, etc.

Entomophilous or *insect-pollinated* flowers are by far the most common. Almost all ordinary flowers are insect-pollinated. They are characterised by an attractive corolla or perianth, in many cases they have a sweet scent, and often contain honey or a large amount of pollen. The colour, or fragrance, or both serve as a signal for insects to approach in prospect of honey or pollen. The honey (*nectar*) is a sweet secretion collected at the bottom of the corolla, or in a special reservoir (called *nectary*, fig. 170 s.), and constitutes an important food for certain insects. The pollen also is a very nutritious food for insects, and in flowers which have no honey a larger quantity of pollen is formed. An insect in search of food visits a flower, sips the nectar or collects the pollen, and as it flies from flower to flower it unconsciously acts as the pollinator, for some of the pollen sticking to its tongue or body can not fail to touch the stigma of the flowers visited. The pollen-grains are not dry and dusty,

as in wind-pollinated flowers, but are sticky, so that they easily adhere to some part of the insect's body. The surface of the pollen bears spine, warts, or similar projections (see figs. 202, 203) and this ensures a safe landing on the stigma. The latter too is similarly formed; it is not large and feathery as in wind-pollinated flowers, for it is sure to get some pollen from the visitor, but is sticky and rough with spines, etc., corresponding to the surface of the pollen. The form, colour, and scent of the flower vary widely, according to the class of insect whose aid is sought, and the adaptations in some flowers are such that they can be pollinated only by a particular species of insect.

Fig. 220. Fig. 221.



Bee flowers—pollinated by a large bee. St. stamens; S, stigma.

Pollen flowers have little or no honey, no strong scent but numerous stamens which produce a large quantity of sticky nutritious pollen. They are usually large, simple, regular, and rosaceous (p. 107) in form, and offer only the freely exposed pollen to their visitors. The visitors are chiefly bees and beetles, though other insects also come, but butterflies and moths do not eat or gather pollen so that their visit is only casual. Rose, Poppy, Mexican-poppy (Shealkanta—*Argemone mexicana*), Magnolia, Portulaca, Lotus, Water-lily, Gourd, Pumpkin (male-flowers) etc., are pollen-flowers. Bees and humble bees are the most industrious pollen collectors. The pollen is produced in such large quantities that the insects roll in them and come out smeared all over with a golden dust.

Honey flowers are by far the most common. They economise their pollen and instead secrete a sweet or scented liquid, called honey or nectar which is offered to insects. The flowers are usually small with a few stamens, often irregular in shape, brightly coloured, or spotted, or streaked, and are so formed as to protect their pollen and honey from

casual visitors. They are highly specialised to be effectively pollinated by different classes of insects, for the larger insects, wasps, beetles and bees, are the most mischievous pollen plunderers. Some are white or pale-coloured, but emit a far-reaching fragrance which serves to attract the insects of their choice. The following are some of the important groups of honey-flowers :—

1. **Butterfly flowers** (*Lepidopterophilous*), visited by butterflies which have a long tongue or proboscis. The flowers also have a long narrow tube at the bottom of which is honey which can only be reached by these butterflies and not by short-tongued insects (wasps, beetles, flies and some bees). They are very brightly coloured with crimson streaks or spots, red being the colour which affects butterflies most. They have no scent, for bright coloured flowers are, as a rule, little scented. Example : Pink, Rangan.

2. **Moth flowers** (*Lepidopterophilous*), visited by moths (the same family as butterflies) which fly about on pleasant evenings at dusk or night. The flowers are like the last but are white and pale-coloured (bright colour being of no use at night), emit a very strong scent, especially at dusk. The common Jasmines, Hasna-hena (*Cestrum nocturnum*), Shephalika (Seuli—*Nictanthes arbor-tristis*), are examples. The flowers are often called **night flowers** for they open at dusk when they are most fragrant, and fall away the next morning, so that they cannot be pollinated except by night-moths. The moths also pollinate with surprising rapidity. Attracted by the strong odour they fly straight to the flower and at once introduce their long tongue into the corolla-tube, and within a few seconds hasten with stormy flight to another flower. In one night hundreds of flower may be pollinated by the same moth. It is for this that the corolla falls off so early and the flowers produce only a few stamens (2 in Jasmines).

3. **Bee flowers** (*Hymenopterophilous*), visited by the various kinds of bee (large bees with short tongues, humble-bees and honey-bees with long tongues, and wasps, are of various forms, but generally irregular flowers such as papilionaceous, bilabiate, and personate flowers fall under this group. The colour also varies widely ; yellow, blue or violet being the most common. Very often the flowers are so highly specialized and their shape so admirably suited as to be visited by a particular kind of bee only, and not by others. Ex : Pea family, Balsams, Orchids, Bakash family, Toolsy family, etc.

4. **Fly flowers** (*Dipterophilous*), visited by various forms of flies, are usually small, of a dull colour, yellowish or white with coloured spots, regular and open in form, and not very attractive

or showy. Some are bad-smelling, but the odour is attractive to some flies, such as carrion-flies and dung-flies which like rotten vegetables, and are pollinated by them. Others conceal their nectar about the stamens and stigma which are stiff and cannot be easily moved by such insects as bees, but by the larger flies which possess a very hard and short tongue. Ex; Kachoo, Akanda, Mango, Neem, Aroids, and other small flowers.

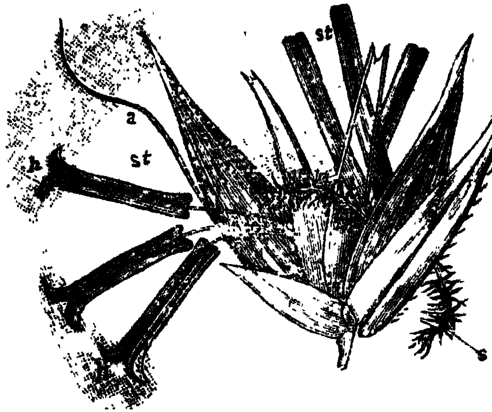


Fig. 222. Wind-pollinated flower of a plant of the Grass-family. The dry dusty pollen (p) escaping from the large pendulous anthers (st) is carried away by the wind. The style (s) is large, branched and feathery, but the stigma is not formed till the anthers are discharged. The flower is dry and husky (magnified 5 times).

Ornithophilous or bird-pollinated flowers are not common. They are very large, of a deep scarlet colour, and secrete a large quantity of honey. They are common in tropical jungles, especially of America (Brazil) where humming birds and honey-birds abound. The flowers are so large that insects (butter-flies, bees, etc.) can not reach the nectar, but the birds mentioned visit them either for the honey or for the insects attracted by the flower and hovering about it. The large highly coloured flowers of the Red Silk-cotton (Simul), Bignonias, Erythrinas (*Coral tree*), Sondal or Indian Laburnum, the Gold Mohur or Krishnachura and the scarlet Poppies and wild Daturas of the hills, are bird-pollinated. The American trees Brownea (*B. hybrida*) and *Amherstia nobilis*, now introduced into this country, have large red coloured ornithophilous flowers.

Zoophilous pollination, or that with the help of other animals, is

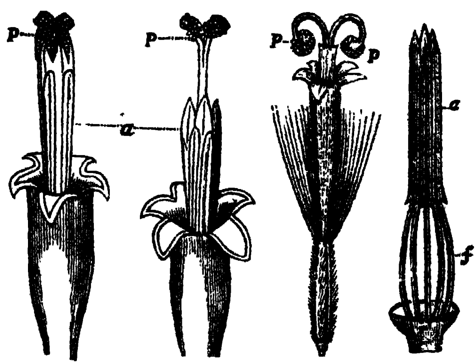
far less common. Some animals unconsciously act as pollinators. Thus swarms of bats may be seen visiting at dusk the large heads of Kadamba flowers which are produced in surpassing profusion on the plant. The bats eat the juicy stamens and during the act pollen-grains are scattered over their body. Similarly small snails and slugs are known to take shelter within the spathe of various species of Arum (Kachoo family). In their movement to and fro they carry pollen from the male to the female flowers.

Hydrophilous pollination :—Water is never used to carry pollen-grains directly, for they are destroyed by it. But certain aquatics make use of water-currents as a passive agent for carrying the male to the female flowers. Thus the common submerged plant *Vallisneria spiralis* is diœcious, bearing male flowers in one plant and female flowers in another. The male flower buds detach themselves from their stalks while still under water, and rise to the surface and then open out with a pair of stamens projecting from the middle of three small boat-shaped sepals. The female flowers borne on long stalks also open out on the surface of water and bear three large projecting stigmas. The small male flowers, drifted by currents of water, become entangled in the female flowers and the projecting stigmas and stamens come in contact. Another example is Hydrilla Verticillata, a slender submerged plant common in our tanks.

Self and Cross-pollination—When the anthers lie close to the stigma pollination may be brought about by the pollen simply adhering to the stigma. This is called self-pollination or *autogamy*. But this is not possible in many cases. Thus when the flowers are unisexual the pollen must come from the male flower to the female flower, and in cases where they are diœcious the pollen must come from the male plant to the stigma of the female plant. This is called cross-pollination or *allogamy*. In the first case (unisexual flowers) two flowers are *crossed*; in the second, two plants of the same species. Even in bisexual (hermaphrodite) flowers self-pollination is not always possible. Thus many grasses and cereals which have both stamens and pistil in their flowers, so develop that while the anthers are dangling in the air and giving out little clouds of pollen-dust (anemophilous), the stigma remains immature without the receptive

spot. The result is that the pollen of a young flower is carried by the wind to an older flower which has already discharged its pollen and has just developed the receptive spot on its stigma ; the younger flower pollinates the older, *i.e.*, the two are crossed. There are various other devices in flowers by means of which self-pollination, or the pollination of the stigma of a flower with its own pollen, is often prevented, and cross-pollination is aimed at. The reason is that by *intercrossing* better, stronger and often more numerous seeds are produced than by self-pollination.

Fig. 223. Fig. 224. Fig. 225. Fig. 226.



Flowers of a capitulum showing gradual development of the stamens and the style. Fig. 223, the anthers have discharged pollen-grains (p) inside the tube formed by the anthers (a) ; 224, the same later stage, showing the elongated style carrying the pollen at its top ; 225, the same later stage, showing the formation of the bifid stigma—the pollen (p) remaining at the ends of the stylar branches. Fig 226, the stamens of the flower only ; a, anthers ; f, filament.

Allogamy may take place in either of the two ways : (1) when the crossing takes place between flowers of the same *individual* plant, it is called **geitonogamy**, and (2) when between flowers of *two* individuals of the same species, it is called **xenogamy**. For instance, in the Papaw and

the Toddy-palm the pollination must be xenogamous, for the male flowers are in one plant and the female flowers in another; the *two* plants are crossed. Where hermaphrodite flowers are crowded together (as in the Sunflower family) it is very likely that the wind or insects will carry the pollen of one flower to the stigma of its neighbour; in other words the pollination is geitonogamous.

Cross-pollination takes place with the help of wind, insects, etc., which carry the pollen from one flower to another. The adaptations found in flowers for securing inter-crossing are :—

1. **Dicliny** or unisexuality. Unisexual flowers must be necessarily crossed. When they are monœcious, as in Cucumber, Gourd, and other plants of the family, the pollen must be carried from the male flower to the female flower borne either on the same plant or on another plant. When they are diœcious, as in Papaw, Toddy-palm, Date-palm, etc., the pollen must come from the male plant to the female plant.

2. **Dichogamy.**—In many hermaphrodite flowers there is a difference in the time of maturity of the anther and the stigma. This condition is known as dichogamy. In some plants the anthers of the flower mature and shed pollen before its stigma develops the receptive spot—this is termed *protandry*; while in others the stigma of the flower develops and receives pollen long before the anthers are ripe—this is termed *protogyny*. The flower, then, though bisexual in form, is unisexual in function. For the protandrous flower is at first behaving like a male, and then, when the pollen-grains are discharged, like a female. The protogynous flower is at first female and then male. Of course all the flowers of the plant are either protandrous or protogynous. A protandrous flower *pollinates* an older flower, and *is itself pollinated by* a younger flower. A protogynous

flower is *pollinated by* an older flower, and *itself pollinates* an younger flower. The flowers of the Sunflower family are as a rule protandrous. The capitulum (p. 86) consists of several ligulate ray-florets, and numerous disc-florets. The ray-florets are brightly coloured and serve to attract insects. They are often only pistillate. The disc-florets are hermaphrodite and have a tubular corolla from the mouth of which projects the tube formed by the syngenesious anthers. The pollen is early discharged into the interior of this tube. The style at this time lies hidden at the bottom of the anther-tube; it then slowly lengthens, pushes the pollen

Fig. 227.

Fig. 228.

Dichogamous Moth flowers of *Clerodendron infortunatum*.

Fig. 227. Flower opened the 1st day, showing protandrous stamens (*st*), style (*s*) still immature. Fig. 228. The same, showing position of recurved stamens (*st*) now discharged and withering, and of the style which has now developed the stigma (*s*).

before it out of the tube and holds it in the path of insects. The insects crawling over the surface of the capitulum take away the pollen-grains on their body. The style in the meantime has elongated still more, and at length it divides itself into two branches on which the stigmatic receptive spot is then developed. As all the flowers are protandrous, shedding pollen-grains long before the stigma is formed, and as the flowers open circle after circle, it

follows that the pollen of the capitulum which is just opening must be carried away to an older fully opened capitulum, the stigmas of which become thus pollinated; and further, in the same capitulum, gradually as the inner circles of florets open, their pollen easily comes to the stigma of the outer circles. The ray-florets are all female, so that as the first circle of disc-florets opens the pollen for pollinating the ray-florets is at hand; the protandrous flowers pollinate older flowers, and are themselves pollinated later on by younger flowers. Almost similar is the case in the Java or Cotton family. Here the filaments form a tube (monadelphous), which at first conceals the style. The

Fig. 229. Fig. 230.

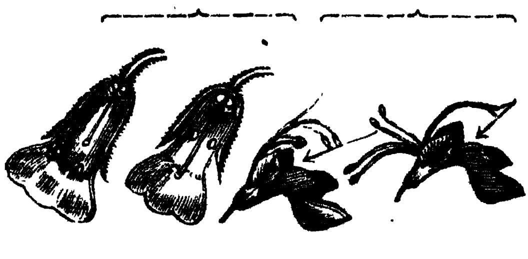


Fig. 229. Dimorphic heterostyled flowers; A, a flower with anthers at a higher level than the stigma; B, just the reverse. Legitimate union takes place between stamens and styles of equal length.

Fig. 230. Stamens and styles interchanging positions—an instance of dichogamy, A, anthers mature, style turned up being yet too young. B, stamens turned up being now too old; the style now has developed its stigma and has come to occupy the position the stamens had in A; the arrow indicates the path of visitors.

anthers begin to shed the pollen-grains soon after the flower opens. In a short time the anthers are empty and dry up, insects having carried away the pollen. About this time the style peeps out of the staminal tube, gradually elongates more and more and divides into five or more branches bearing stigmas. Now this stigma can only be pollinated by the pollen of another flower which has just opened and is shed-

ding pollen; *i.e.* by a younger flower. In some dichogamous flowers the stamens and the style interchange their position so that at one time the anthers only lie in the path of the insect, and at another only the style with its stigma. For instance, in the common Ghentu (*Clerodendron infortunatum*, a small shrub flowering in the cold season) the stamens are at first straight in the flower that has recently opened but the style is bent down, as shown in fig. 227. The flowers are thus protandrous; they emit a strong smell at dusk and attract night-moths. The moth that comes for nectar, hidden far below in the corolla tube, must pass its long tongue into this tube, and as it soars in front of the flower the wings must touch the anthers. Then as it visits a flower which opened the night before, it finds the style occupying the same position as the stamens of the newly opened flower, and the bifid stigma which has now been developed receives the pollen brought from the younger flower. The anthers after discharging their pollen in the first night roll up or curve down (fig. 228), and then the style straightens on the second evening, forms the stigma, and receives pollen. There is absolutely no chance of self-pollination.

Protogynous flowers are found in the Mustard, Potato, Brinjal, etc., where the stigma is sticky while the anthers are yet young. In many plants which produce unisexual flowers, especially those that are anemophilous, protogyny is very common. For instance, in plants which bear male and female flowers, the latter mature first, so that they are fertilised by pollen coming from another individual of the same species (xenogamy.)

3. **Herkogamy.**—In many *homogamous* flowers, *i.e.* those in which the anthers and stigmas ripen at the same time (as opposed to dichogamous flowers), the relative position of the stamens and the style is such that self-pollination is difficult; for often the stamens are bent out towards the circumference of the flower and the style is central, and in many cases the anthers burst *extrorsely* *i. e.* facing the

petals. This may be seen in the garden Nasturtiums and Portulaca.

4. **Heterostyly.**—Sometimes the stamens and styles are of different length ; this is known as *heterostyly*, and is very common. In some plants there are two kinds of flowers : some with long stamens and short styles, others with long styles and short stamens, the relative lengths being reciprocal, as shown in fig. 230. The anthers and stigmas are so situated that insects visiting several flowers touch correspondingly placed organs with the same part of their tongue. Thus a short style is pollinated by short stamen, a long style by a long stamen. This is the *legitimate pollination* ; it is *illegitimate* when pollen of stamen comes to the stigma of a short style. Better seeds are produced by a legitimate crossing than when it is illegitimate. Such flowers are said to be *dimorphic*. Similarly there are *trimorphic* flowers with three different lengths of styles and stamens, long, short, medium.

Self-pollination can take place only in hermaphrodite flowers, but not in all, for many flowers are either dichogamous, or if homogamous, are often heterostyled or herkogamous. But still self-pollination is very common in flowers. And though by crossing better seeds are produced, it is far more difficult to secure it than self-pollination by which means at least the production of seeds is certain. Certain flowers must of necessity be crossed, but in hermaphrodite flowers there are also adaptations for self-pollination on the failure of intercrossing through want of wind or insect-visit.

1. In the simplest cases the anthers are close to the stigmas and cover the latter with pollen as the flower opens. This happens in a number of small annual plants which live for too short a period to wait for insect-visit and risk intercrossing.

2. In many flowers the stamens are at first directed

outwards but later incline towards the stigmas and pollinate them (fig. 231). This is seen in the garden Portulacas

Fig. 231. Self-pollination in the flowers of an Umbellifer. A.B.C.D.E. are the successive stages showing how stamens curl inwards and sprinkle pollen on the stigma.

the flowers of which open for only a few hours in the forenoon. They are pollen-flowers, and at first stand open with stamens bent on one side and the style bent on the other. When touched the stamens recoil like a spring and scatter the pollen-grains; this they do also at noon when the sun is warm, and thus sprinkle pollen on the petals. Soon after the petals fold up, the flower is closed, and the stigma become covered with pollen. In Kala-jira (*Nigella sativa*) the stamens at first stand horizontally, but later on they stand up one by one and the five styles being bent down, the anthers touch the stigmas and pollinate them.

3. Self-pollination by a similar folding up of the petals is also seen in the common Shealkanta (Mexican Poppy). The flowers are large yellow pollen-flowers; the filaments diverge away from the centre while the stigma is central. Insects rarely visit the flower, but self-pollination takes place by the pollen sprinkled on the petals adhering to the stigma when the flower closes at maturity. Flowers of Morning-glory and other Ipomæas also exhibit a similar closing up of the petals in the afternoon, and as they remain open only during the forenoon, they are self-pollinated if not crossed by insects previously.

4. Sometimes the filaments and style become inter-

twined, so that pollen is brought in contact with the stigma, as in the common Four-o'clock plant (Krishnakali), the flowers of which also close up at dusk.

5. In the Cotton and in the Sunflower families there is a very peculiar means of securing self-pollination on the failure of inter-crossing. The protandrous flowers shed their pollen long before the style develops the stigma. Later on, if inter-crossing has not already taken place with the help of insects, the style goes on dividing more and more and the stylar branches, on the inner surface of which is developed the receptive spot, go on curling more and more, till they come into contact with some of the pollen sticking to the filaments (in the Cotton family) or to the pappus (in the Sunflower family).

6. In the cruciform flowers of the Mustard and Radish there are two short stamens with anthers below the stigma, and four long stamens with anthers at the same level with the stigma (fig. 232). The flowers are slightly protogynous, so that insects bring about cross-pollination. At first the shorter stamens ripen and give away pollen, but if insects fail to visit, the longer stamens shed pollen on the stigma when the flower is about to fade, and thus secure self-pollination at the last moment.

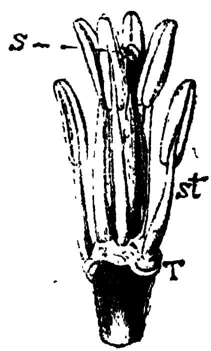


Fig. 232. Tetradynamous Stamens (st) and Style with stigma (s) of a crucifer.

Cleistogamy :—Many plants produce in addition to ordinary open flowers small bud-like flowers which remain permanently closed, but which notwithstanding produce fruits These are called *cleistogamous* flowers, as opposed to the ordinary open flowers called *chasmogamous* flowers. Cleistogamous flowers are self-pollinated and developed

at seasons less favourable for cross-pollination. They are small, greenish, bud-like flowers without, or with an inconspicuous, corolla, with the anther and stigma lying close together, so that the pollen easily reaches the stigma. They lie near about the ground, hidden behind the leaves, and are formed generally in smaller plants which live in muddy or marshy places, where insects are less likely to pay a visit. Common instances are *Commelina bengalensis* (Kanchira), several species of Violets, Oxalis, etc. The Jack-fruit (Kanthal) tree is known to produce underground big Jack-fruits which are supposed to arise from the cleistogamous pollination of female spikes developed under the ground.

SUMMARY.

Pollination may take place with the help of (a) wind, (b) insects, (c) birds, or (d) other animals, and sometimes of (e) water.

1. **Wind-pollinated** or anemophilous flowers are small, dry, colourless, odourless, honeyless, but produce a large quantity of dry, dusty, light pollen easily blown about by the wind, and large feathery stigmas to catch the pollen readily—*e.g.* grasses, cereals.

2. **Insect-pollinated** or entomophilous flowers are large, coloured, showy, attractive, often scented and with honey, and produce sticky pollen-grains with rough spiny outer walls and small sticky stigma. They may be.—

A. *Pollen-flowers*—large, regular, simple flowers with no honey but abundant pollen,—*e.g.* Rose, Poppy, Cucumber.

B. *Honey-flowers*—small flowers especially adapted with only a few stamens and with honey, so formed as to protect both from useless waste. These form the majority and are—

1. *Butterfly flowers*, which have a long corolla-tube and high colour in the spreading corolla-lobes—*e.g.* Pink.
2. *Moth flowers*, similar but white and highly fragrant—called also night flowers, *e.g.* Jasmines.
3. *Bee flowers*, irregular flowers, such as papilionaceous, bilabiate, personate, etc, which have special means of concealing their honey.
4. *Fly flowers*, small, round, regular, bad-smelling or odourless, dull yellowish or purple-coloured flowers visited by flies, *e.g.* Akanda, Arum.

3. **Bird-pollinated** or ornithophilous flowers are not very common. They are very large and showy, with a large quantity of honey; pollen and stigma are as in (2).

4. **Zoophilous** flowers or those pollinated by midges, mites, snails, slugs, bats or other animals, are rather rare.

5. **Water-pollinated or hydrophilous** flowers are very rare.

The different ways in which flowers are pollinated are—

1. *Autogamy* or self-pollination—stigma of a flower fertilised by its own pollen; only possible in bisexual flowers.

2. *Allogamy* or cross-pollination—stigma fertilised by pollen of another flower. This is either,—

   A. *Geitonogamy*, when both flowers are on the same individual plant, as in capitulas or umbels where the flowers are crowded.

   B. *Xenogamy*, when they are on different individuals of the same plant, as in diœcious flowers.

Inter-crossing, which gives rise to better seeds, is secured by :—

1. *Dicliny* or unisexuality of flowers.
   A. Monœcious flowers must inter-cross.
   B. Diœcious flowers must cross two individuals.
2. Dichogamy—anther and stigma of a flower maturing at different times to prevent self-pollination. Dichogamous flowers are functionally unisexual at a time.
   A. Protogyny—stigma maturing before anther.
   B. Protandry—anther maturing before stigma.
3. Heterostyly—different lengths of stamens and styles even when the flowers are homogamous.
4. Herkogamy—stamens and style divergent or widely distant, though they are homostylous and homogamous.

QUESTIONS.

1. How would you distinguish between wind-pollinated and insect-pollinated flowers; Describe the adaptations found in each. Give examples.

2. Describe the various forms of insect-pollinated flowers.

3. What are : pollen-flowers, moth-flowers, bee-flowers, night-flowers, chasmogamous, cleistogamous, dichogamous, allogamous, heterostyled, protandrous, dimorphic, and xenogamous flowers. Give examples.

4. Distinguish between self and cross-pollination. What is the advantage secured by the latter ?

5. Give an account of the various ways in which intercrossing is secured by flowers.

6. Describe pollination in Sunflower, Pea, Java, Rose, Grass, Kadamba, Colocasia, Clerodendron, Gourd, Hasna-hena, Pink, and the Jasmines.

CHAPTER XI

THE FRUIT.

The fruit is developed from the ovary of the flower as a result of fertilisation. After fertilisation various changes take place in the parts of a flower. Generally the anther and stigma rapidly wither while the filament and style remain for a short time; petals fall, and so do the sepals (except where they are persistent, p. 104), the ovary is enlarged to form the fruit, and the ovules mature into seeds. In simple cases the ripe ovary forms the fruit; its wall becomes the *pericarp* or fruit-wall. In many cases, however, other parts of the flower, such as the thalamus, the calyx, the bracts, and so on, unite with the ovary so that the fruit consists not simply of the pericarp but also of the other parts. Thus the fruit of Chalta (*Dillenia indica*) is made up of the persistent and enlarged sepals which enclose the true pericarp containing the seeds. And when the ovary is inferior, the thalamus or calyx-tube is adherent to it and the two grow up together to form the fruit. This is seen in the Guava, Apple, Cucumber and other *inferior* fruits (so called because they are formed from inferior ovaries), where the withered sepals form a crown at the top of the fruit. The fleshy part comes from the ovary together with the hollow thalamus which encloses it in the flower. Such fruits are sometimes distinguished as false or *spurious fruits* or *pseudocarps*, the term pericarp being not strictly applicable. The stimulus given to a flower by fertilisation may, however, extend still further, and all the flowers of an inflorescence may grow up so as to form a single fruit—all the ovaries, perianths, bracts, etc., joining

to form a single mass; *e.g.*, the Pineapple, the Jack, the Fig, etc.

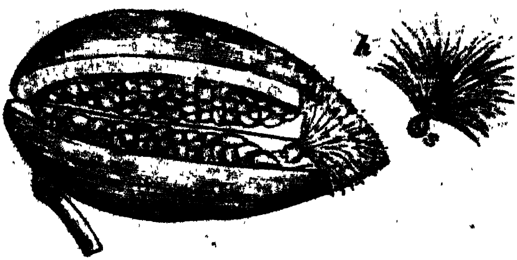


Fig. 233. Follicle of Akanda; to the right the seeds with a tuft of hairs.

Fig. 234. Pyxis of Portulaca.

Kinds of fruits—A fruit which is formed from a number of crowded flowers is termed a *collective* or *multiple* fruit; it results from a whole inflorescence and is hence also termed an *infrutescence*. A fruit which is formed from the ovary of a single flower is a *simple fruit*; it may be the ripe ovary alone, as in Pea, or the pericarp with the persistent and enlarged calyx, as in Chalta, or the ovary with the thalamus, as in Guava, Apple, etc. Where the flower has a number of separate carpels (apocarpous gynœcium), as in Magnolia, Rose or Lotus, each ovary matures into a fruit and the collection is called an *aggregate fruit*.

Simple fruits, or those arising from the single ovary (superior or inferior) of a flower, may be either *dry* or *succulent*. Where the ovary is superior, it matures into the fruit, the carpel becomes the pericarp which may be dry as in Pea, Mustard, or succulent as in Mango, Peach, Brinjal. Where the ovary is inferior it is adnate to the wall of the thalamus, the two grow together and ripen into a fruit which has no true pericarp but a pseudocarp; this too may be either dry (Sunflower), or succulent (Guava, Apple).

Dehiscence of fruits.—When the fruit is mature and the seeds are ripe, the carpels usually break up so as to allow the seeds to escape. The fruit in this case is *dehiscent.* But some fruits are *indehiscent,* falling to the ground entire, and the seeds eventually reach the soil by the decay of the fruit-wall. By dehiscence the pericarp breaks up into pieces called *valves.* These are usually cut off lengthwise along either the ventral or the dorsal sutures of the carpels, but in some cases are formed irregularly and not by the splitting of the sutures. The various modes of dehiscence are:—

1. Sutural or regular dehiscence.—

1. When the fruit is formed from a single carpel it opens generally by the ventral suture only, as in Akanda (fig. 238), Nayantara (*Vinca*), etc., or sometimes by the dorsal suture only as in Magnolias. Such fruits, called *follicles,* have no valves, but in the Pea family both the sutures open, so that there are two valves. Such a fruit is called a *legume* (fig. 240). The dehiscence is marginal.

Fig. 235. Fig. 236. Fig. 237. Fig. 238.

Septicidal. Loculicidal. Septifragal dehiscence of capsules (diagrammatic).

2. When composed of several united carpels, the dehiscent fruit is called a *capsule.* Its dehiscence is said to be:

(A) *Septicidal,* when the *septa* or partition walls are split up and separated, so that the fruit is rendered into its original carpels, each valve thus formed representing a carpel (fig. 235).

(B) *Loculicidal,* when each carpel splits open along the dorsal suture, *i.e.,* by its back, so that each valve consists of a half of each of two contiguous carpels (fig. 236).

(C) *Septifragal,* when in either of the above two forms of dehis-

cence the placentas bearing the seeds remain united in a central column and the valves alone fall away. Thus a capsule may be septicidally septifragal (fig. 238), or loculicidally septifragal (fig. 237) as in Datura (fig. 239).

II. **Irregular dehiscene,**—Capsules may also have

1. *Porous* dehiscence, as when the pericarp breaks at some parts by circular pores or holes through which the seeds escape, *e. g.*, Poppy (fig. 243).

2. *Transverse or circumscissile* dehiscence, when the pericarp breaks up into two cup-shaped parts, the upper part falling off like a lid, as in Portulaca, Cock's-comb (fig. 234).

Fig. 239.

Capsule of Datura breaking septifragally into 4 valves.

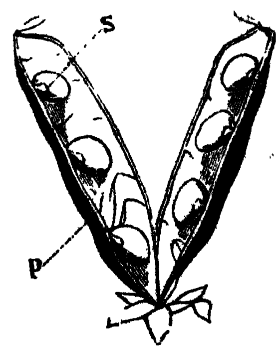


Fig. 240.

Legume of Pea—P, pericarp, S, seeds attached to the marginal (ventral) placenta.

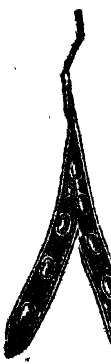
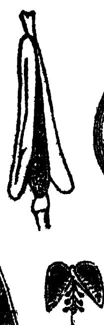
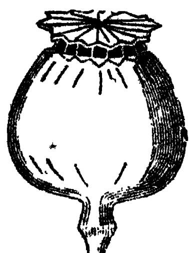
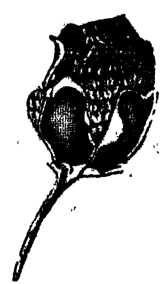
Dry dehiscent fruits.—1. The *follicle* is a dry one-celled many-seeded fruit, formed from a single carpel, and usually dehiscing by the ventral suture, as in Akanda (fig. 233), less commonly by the dorsal suture, as in Magnolia.

2. The legume is a dry one-celled many-seeded fruit, formed from one carpel like the last but dehiscing by both the ventral and dorsal sutures into two valves *e. g.* Pea, Bean,

Pulses, Indigo, etc. A modified form of the legume is called the *lomentum*; it is transversely constricted between the seeds and is generally indehiscent or breaks into one-seeded parts at the constrictions, *e.g.* Lajjabaty (Sensitive plant), Acacia (Babla), Sisoo.

The Tamarind fruit is a succulent loment; its pericarp has three distinct parts; a brittle *Epicarp* on the outside, then the pulpy acid *Mesocarp*, and a leathery or tough *Endocarp* enclosing the seeds in separate chambers. The Ground-nut (*Chiner-badam*) has a 2-3 seeded indehiscent loment which is developed in a peculiar manner; after fertilisation the flower-stalk bends down and the ovary is driven into the earth to ripen underground. In the Sensitive plant the pericarp of the loment gradually crumbles away, leaving the two sutures intact as a thin frame from which the seeds are shaken out by the wind.

Fig. 241. Fig. 242. Fig. 243. Fig. 244.

Legume — Siliqua, Silicula — Porous Capsule of Poppy — 3-valved capsule of Cotton.

3. The **siliqua** is a dry two-celled many-seeded syncarpous fruit, formed from two carpels, and dehiscing by two valves from below upwards, *e. g.* Rape, Mustard. It is formed from two carpels which unite by their margins to form two parietal placentas, but subsequently a *false* partition or *septum* stretches between the two making the ovary

2-celled. When mature the two valves break away from the false septum which then remains behind as a persistent *replum* with seeds attached to the margin on both sides (fig. 242). A short and broad siliqua, as in the garden annual Candytuft (*Iberis*), is termed a *silicula* (diminutive of siliqua).

In some cases, as in the Radish (Moola), the siliqua is jointed and indehiscent, breaking transversely into one-seeded parts, it resembles the lomentum and is hence sometimes said to be *lomentaceous*.

Fig. 245.

Cypsela of Sunflower.

Fig. 246.

Samara of Madhabilata

Fig. 247.

Samara of Sal

Fig. 248.

A Cremocarp

4. The **capsule** is the general term applied to all dry syncarpous dehiscent fruits (see p. 140). It may be one-celled (Latkan—*Bixa Orellana*), or more than one-celled (Cotton, Java), and may break up into two or more valves. Thus the Latkan fruit bursts into two valves, Cotton fruit (fig. 244) into three, that of Morning-glory and Datura into four, of Java into five, and so forth.

5. The *pyxis* or *pyxidium* is a transversely dehiscing capsule, the upper part falling off like a lid, as in fig. 234—*e. g.*, Portulaca, Cock's-comb, Natya-Shak, etc.

Dry indehiscent fruits are usually one-celled and one-seeded and are often very small and seed-like.

1. The *achene* is a small dry one-seeded superior fruit, the pericarp of which is applied to the seed but is separable from it—*e. g.*, the Lotus (fig. 258) the garden Clematis and *Naravelia* (Chagul baty—fig. 264) where the separate carpels of the flower mature into small seed-like achenes.

2. The *caryopsis*, the term applied to the fruit of Grasses and cereals (the grains of rice, wheat, barley, etc., are really fruits), is very similar to the achene, but the pericarp here is very thin and quite inseparable from the seed (the husks are bracts).

3. The *cypsela* is a small seed-like fruit like the achene from which it differs in being formed from an inferior ovary. It is the characteristic fruit of the Sunflower family. In many cases it is crowned by a persistent hairy pappus (p. 105), as shown in figs. 262-63. In Sunflower (fig. 205) the cypsela has two wings at the top; in Marigold and Zinnia it is topped by the segments of the calyx; in the weed Kokshim (*Vernonia cinerara*) and the garden plant *Helichrysum* the cypsela has a tuft of fine hairs (fig. 262), while in some cases the pappus is borne on a long stalk at the top of the fruit (fig. 263).

4. The *samara* is a *winged* achene; that is, the pericarp is extended into thin flat membranous wings which help the fruit to be dispersed by the wind.—*e. g.* Madhabilata (*Hiptage Madhoblota*), Red Santal-wood (*Pterocarpus santalinus*), Bija-sal (*P. Marsupium*), etc.

A winged fruit is called a samara; but the wing is not always a part of the pericarp. Thus the samara of Sal (fig. 247) has three large wings and two smaller ones developed from the five lobes of the persistent calyx the lower part of which encloses the fruit.

5. The *nut* is a dry one-celled indehiscent fruit with a thick and woody pericarp.

6. The *utricle* is an achene with a thin papery pericarp within which the seed rattles. It is not common.

Schizocarpic fruits, or schizocarps, are dry syncarpous 2 or more seeded fruits which when ripe split up into a

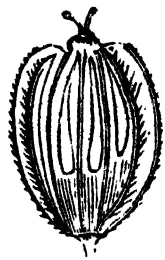
Fig. 249. 

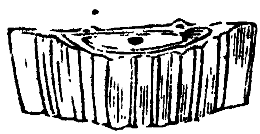
Fig. 250. 

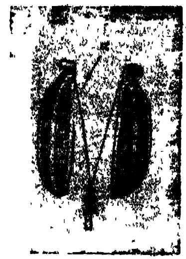
Fig. 251. 

Fig. 249. A cremocarp with the persistent bifid stigma at the top. Fig 250. Transverse section of a mericarp showing the single seed and the fruit-wall. Fig 251. Cremocarp showing the separated mericarps attached to the carpophore (a).

number of one-seeded parts each enclosing a solitary seed. The one-seeded parts are dry and indehiscent like achenes and are called *mericarps.* The difference between a schizocarp and a capsule is this: in a capsule the pericarp bursts and the seeds are set free, but a schizocarp breaks up into its component *carpels* (mericarps) each *enclosing* a seed.

The *cremocarp* is the characteristic fruit of the Carrot and Anise family. It is a dry syncarpous two-celled two-seeded fruit formed from an inferior ovary composed of two carpels. When ripe it breaks up into two mericarps (figs. 249—51) which remain for sometime attached to a prolongation of the axis called the *carpophore*; each mericarp encloses a single seed.

Succulent or fleshy fruits are naturally indehiscent. They may be soft and pulpy throughout (Guava, Grape), or with a firm rind (Gourd, Water-melon), or fleshy externally and hard internally (Mango, Peach). They may arise either from superior or from inferior ovaries. When from

a superior ovary, the fruit-wall is the true pericarp ; when from an inferior ovary, it is a *pseudocarp*, *i.e.*, a false pericarp formed from the hollow thalamus with which the wall of the ovary is united. The fleshy edible portion is often called the *sarcocarp* (*sarcos* = flesh).

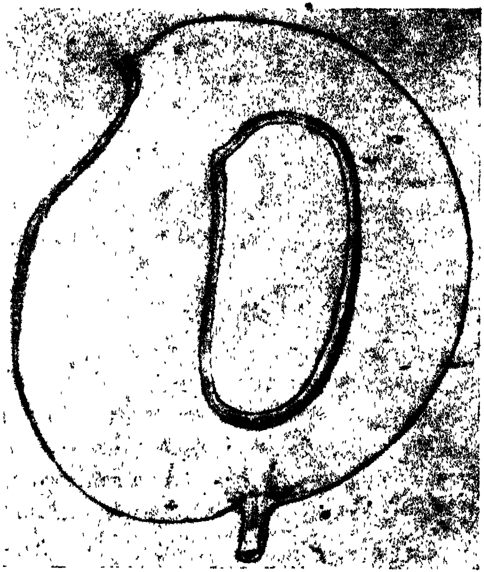


Fig. 252. Drupe of Mango cut vertically.

The **drupe** is a superior, usually 1-seeded, succulent fruit with a hard *stone* enclosing the seed, *e.g.*, Mango, Peach, Almond, Cocoanut, Hog-plum, etc. The pericarp consists of three parts : the outer skin or epicarp, the inner stone or endocarp, and between the two the fleshy portion or mesocarp. The endocarp forms a hard shell or stone which encloses one or more seeds till germination, when it splits open to allow the seedling to come out. Drupes are stone-fruits.

The drupes arise from a single superior mono-carpellary ovary, as in Peach, Almond, and Mango. Those of Hog-plum, Cocoanut, etc., arise from superior, syncarpous many-celled ovaries which during ripening develop but one cell and one seed and the rest are often suppressed. The Cocoanut fruit arises from a superior 3-celled ovary, but during ripening only one cell grows with a single seed, the other two are abortive; so too in the Betel-nut. The Tal fruit, however, similarly arises from a superior 3-celled ovary, and [illegible] cells develop in the fruit, each with a single seed and surrounded by a distinct endocarp, so that there are three stones in the ripe fruit. The Jujube (Kool) is a drupe with a 2-celled, 2-seeded stone or endocarp. Other instances are the Neem, the Kala-jam (fig. 256). The mesocarp is usually fleshy and forms the edible sarcocarp, as in Mango and Peach. But it is sometimes tough as in Almond, or fibrous as in the Cocoanut and Betel-nut, hence called *fibrous drupes*. In the Hog-plum it is spongy but full of a juicy pulp: so too in the Tal.

The **berry** is a term applied generally to all fruits with seeds imbedded in a uniformly soft pulp. The endocarp and mesocarp can not often be distinguished, as both

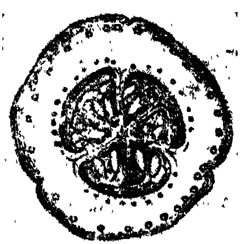


Fig. 253. Cross-section of pepo of Cucumber. The three placentas project inwards where each is forked and reflexed bearing ovules at the end.

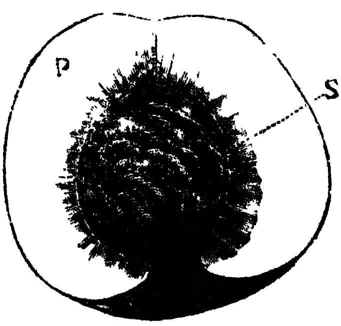


Fig. 254. Drupe of peach; S, the stone or endocarp, P, the fleshy pericarp.

form the pulp (sarcocarp), with the epicarp as a thick or thin skin. The seeds have no stone as in a drupe but are themselves hard. It may be superior (Brinjal, Grape,

Papaw, Tomato, Tepari) or inferior (Guava, Banana), and has usually numerous small seeds, but may have a single large seed also, as in Date.

The Date fruit is a berry and not a drupe, for the 'stone' is really a seed and not the endocarp. The outer thin skin of the fruit is the epicarp, the pulpy portion eaten is the mesocarp, while the endocarp is a thin papery layer surrounding the stony seed.

The Guava fruit arises from an inferior 4 or 5 celled many-seeded ovary, the succulent portion being partly derived from the hollow thalamus adnate to the ovary; the sepals persist as a crown of scales on the top of the fruit. The epicarp (so called) in some varieties forms a very thin layer which is not taken off when the fruit is eaten. Similarly, the Banana fruit arises from an inferior three-celled many seeded ovary; here the epicarp forms a rather thick skin.

The Grape is formed from a superior 2-celled ovary with 3 or more seeds, but the juicy matter comes mainly from the placenta and not from the pericarp.

Fig. 255.

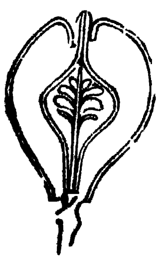


Fig. 256.

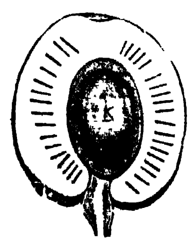


Fig. 257.

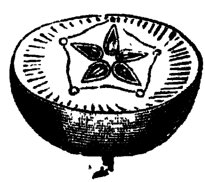


Fig 255. Vertical section of pome of Apple, the innermost layer enclosing the seeds; fig. 257, the same in cross-section, showing the 5-celled core.

Fig. 256. Vertical section of the drupe of Kala-jam; K, the seed enclosed in a hard endocarp.

The pepo, the name given to the large fruit of the Gourd, Melon, Pumpkin, Cucumber, etc., is a modified form of the berry. The fruit has a hard rind which encloses a large sarcocarp in which numerous seeds are imbedded as in a berry. It arises from an inferior one-celled ovary with three parietal placentas, either surrounding a central

cavity (Gourd) or prolonged into it as a coherent fleshy mass in the centre (Water-melon—Turbooj); see fig. 253. It forms a pseudocarp (p. 138), for the adnate thalamus of the inferior ovary grows along with it and forms the rind on the outside.

The **hesperidium**, as the fruit of the Orange and Lemon is called, is a fleshy superior **syncarpous** fruit in which the epicarp and mesocarp form a separable rind (the outer oily skin is the epicarp, the underlying white layer is the mesocarp), and the endocarp forms a thin membranous lining of the chambers or cells of the fruit. The seeds are attached to the inner angle of these chambers and the pulpy matter consists of numerous juicy hairs which arise from the walls of the endocarp.

The **pome**, the fleshy indehiscent fruit of Apple and Pear, arises from an inferior syncarpous ovary which is adnate to the hollow thalamus. The outer fleshy part of the

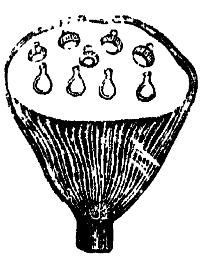
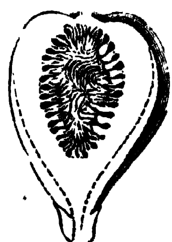
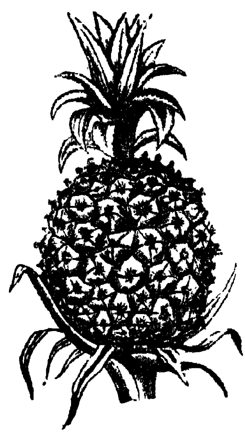




Fig. 258. Fruit of Lotus. Fig. 259. Fig. Fig. 260. Pine-apple.

fruit is the swollen receptacle, the horny core inside (figs. 255, 257) being the true fruit developed from the 5-celled ovary and enclosing the seeds. It is a pseudocarp, the real

pericarp being inside, surrounding the seeds as a thin cartilage-like layer.

An aggregate fruit arises from the free carpels (apocarpous gynoecium) of a single flower. It is usually a collection of single fruits, such as follicles, achenes, berries, etc, formed from the separate ovaries of a flower. Such a cluster is termed an *etaerio*. Thus in the Champaka (fig. 157) and Magnolias the numerous separate ovaries of the flower mature into so many follicles; the fruit is an *etaerio of follicles*. In the Rose the hollow thalamus (fig. 159) contains several free carpels each of which matures into a small achene; the "hip" of the Rose, as the fruit is called, is an *etaerio of achenes*.

The Ata (Custard apple) and Nona (Bullock's heart) are examples of aggregate fruits in which the separate carpels have so united during ripening as to look like a single simple fruit. The numerous free carpels in the flower are densely packed on a slightly raised thalamus; as the cluster grows each carpel matures into a berry, but their tips cohere more or less to form a continuous protective layer inside which lie the separate fleshy pericarps each enclosing a hard seed.

A better example of an etærio of achenes than the Rose is the Chagul-baty (*Naravelia zeylanica*), a wild hedge-climber, and the garden Clematis. The achenes are here collected on a slightly conical stalk, and each has a long tail-like feathery persistent style (fig. 264.).

The fruit of the Lotus (fig. 258) is a peculiar form of aggregate fruit. Here the thalamus is enlarged into a top-shaped body (gynophore). The upper surface of this is like a honey-comb, and in each "cell" a carpel is sunk. When ripe the carpels form hard achenes which rattle in their sockets or cells.

Multiple or collective fruits consist usually of the perianth leaves, bracts, as well as the ovaries of several flowers, commonly of all the flowers of an inflorescence united into one, and are hence also called infrutescences (or infructescences). They are all succulent.

The *sorosis* is a multiple fruit formed from a spike of flowers,—*e.g.* the Pine-apple, the Jack (Kantal), and the Mulberry.

The *syconus* is a multiple fruit in which the rachis of the inflorescence forms a closed and hollow fleshy mass enclosing numerous seed-like fruits (achenes),—*e.g.,* the Fig, the Banyans.

The *strobilus* is a scaly spike of small fruits at the axil of membranous scales, as in Ganja (Indian Hemp—(*Cannabis Sativa*).

The Pine-apple fruit is developed from a spike of small crowded flowers, each in the axil of a red scaly bract. After fertilisation each flower forms a small fruit, but a great stimulus is given to the whole rachis which grows up into a large fleshy mass with which the bracts become incorporated. The edible portion is this fleshy axis, the 'eyes' being the bracts and fruits which are not eaten. The crown of leaves at the top of the fruit is a prolongation of the axis of the spike; the leaves are sterile bracts.

The Mulberry fruit arises from a spike of female flowers. The perianths here become fleshy and enclose the true fruits, the bunch-like fruit is formed by the coalescence of these succulent perianths.

The huge fruit of the Jack likewise arises from a spike of female flowers. They are crowded on a long rachis which in the fruit grows up like a club. The edible portion of the fruit consists of the succulent perianths each enclosing a membranous pericarp with its seed and seated in the axil of a pulpy bract. The hard spines on the coat of the fruit are the persistent stigmas.

SUMMARY.

CLASSIFICATION OF FRUITS.

A. **Simple fruits,** formed from the single ovary (mono- or syncarpous) superior or inferior, of a flower.

1. DRY and DEHISCENT

Monocarpous, from single carpel—

Opening by one suture (usually ventral)	...	1. *Follicle*
Opening by two sutures (ventral and dorsal)	...	2 *Legume*
A transversely jointed legume ...	...	3. *Loment*
Bi-poly-carpous, from 2 or more united carpels—		
Opening longitudinally into 2 or more valves	...	4. *Capsule*
2 valves breaking away from a replum	...	5. *Siliqua*
A short, broad, flat siliqua ...	...	6. *Silicula*
Opening transversely into 2 cup-shaped parts	...	7 *Pyxis*
Opening irregularly by pores or holes	...	8. *Porous capsule*

Breaking into 1-seeded carpels ...	... 9.	*Schizocarp*
Each of such carpels	... 10	*Mericarp*
A schizocarp of 2 mericarps ...	... 11.	*Cremocarp*
II. DRY and INDEHISCENT, usually 1-celled, 1-seeded :—		
Winged fruits	... 1.	*Samara*
Wingless, with pericarp or wall of fruit		
Thin, and consolidated with seed ...	... 2.	*Caryopsis*
Thin and loose, free from seed ...	... 3.	*Utricle*
Thick and hard, usually free from seed		
Small, superior, monocarpous ...	... 4	*Achene*
Small, inferior, dicarpous, often pappose	... 5.	*Cypsela*
Large achene-like inferior fruit ...	... 6.	*Nut*
III. FLESHY or SUCCULENT, indehiscent, often pseudocarps –		
Homogeneous in texture, pulpy or fleshy throughout	1.	*Berry*
Heterogeneous in texture, wall of 2 or 3 separable parts		
Endocarp stony, superior stone fruits	... 2.	*Drupe*
Endocarp (true pericarp) cartilaginous	... 3.	*Pome*
Endocarp, mesocarp, fleshy; epicarp tough	... 4.	*Pepo*
Epicarp and mesocarp a spongy rind	... 5.	*Hesperidium*

B. **Aggregate fruits** formed from apocarpous ovaries of a single flower, each ovary forming a pericarp which may be dry or succulent. An aggregation of such pericarps is called an ... *Etærio*

C. **Multiple,** collective, or composite fruits, formed from the ovaries and other parts of several flowers.

They are ripened inflorescences called	...	*Infrutescence*
The infrutescence of Fig and Banyans	...	*Syconus*
The infrutescence of Pine-apple and Mulberry		*Sorosis*
A dry scaly spike of fruits ...	...	*Strobile*

QUESTIONS.

1. What is a fruit, and how would you distinguish between true fruits and false fruits ; Illustrate your answer with examples.

2. Give an account of the various ways in which fruits break up, and give a classification of dehiscent fruits ?

3. Give a comparative account of the fruits of Guava, Date, Mango, Apple, Fig, Cucumber.

4. Trace the changes which take place in a flower after pollination.

5. Describe the following and give examples : achene, follicle, samara, pyxis, strobile, schizocarp, pseudocarp, endocarp, sarcocarp, lomentum, siliqua.

CHAPTER XII.

THE SEED.

The direct result of fertilisation is that the ovule develops into a seed. So long as the fertilised ovule grows it draws its nourishment through the placenta and remains attached to it by the funicle. When it matures into the seed the funicle withers, leaving a scar on the seed—the *hilum*.

Soon after fertilisation the ovum of the embryo-sac rapidly develops into a minute plant or germ, called the *embryo*. During this development a mass of food matter is stored in the nucellus of the ovule; this is termed the *albumen*. The albumen may be formed outside the embryo-sac surrounding the embryo and then it is known as the *endosperm*; or it may be formed outside the embryo-sac in the tissue of the nucellus itself, when it is called the *perisperm*. Seeds with both endosperm and perisperm are comparatively few, *e.g.*, Lotus. In certain ripe seeds there is no albumen, neither endosperm nor perisperm, and such seeds are termed *exalbuminous*. The two coats of the ovule mature into the coats of the seed: the outer, which becomes hard, is the *testa*, while the inner, which remains soft and applied to the surface of the *kernel* of the seed, is the *tegmen*. The corresponding parts of the ovule and the seed are:—

Ovule.				Seed.
(a) Embryo-sac	Ovum	...	Embryo	
	Other contents	...	Endosperm	Albumen
(b) Nucellus	......	...	Perisperm	Albumen
(c) Integuments	Inner	...	Tegmen	Seed-coats
	Outer	...	Testa	Seed-coats
(d) Micropyle	......	...	Micropyle	
(e) Funicle	......	...	Funicle	

Outgrowths on the seed often arise on the testa.

1. The *aril* is a fleshy outgrowth from the funicle which grow

like a cup and forms a covering outside the testa of the seed. The edible portion of the Litchee and the Ansphal is an aril and not a part of the pericarp which forms the outer skin only. The fleshy coats of the seeds of the Lotus, Papaw, and the Indian Soap-nut (Ritha—*Sapindus trifoliatus*) are arils. The familiar lacinated *mace* of the Nutmeg (Jayphal—*Myristica fragrans*) is, however, not an aril; it originates about the micropyle and then grows down towards the funicle, and is hence a false aril or *arillode*.

2. Sometimes small tumers or ridges arise on the surface of the testa; these are *strophioles or carunculas* - *e.g.* Castor-oil seed.

3. Often *hairs* arise on the testa. The seeds of Cotton and Red silk-cotton are covered all over with hairs. Sometimes the hairs arise in tufts known as *comas*; as in the small flying seeds of Akanda (fig. 233), Karabi; such seeds are described as *comose*.

4. *Wing-like* appendages are formed on the testa—*e.g.* in Bignonias, Sajina (*Moringa*).

Fig. 261. Winged seed of a Bignonia.

The **albumen** of seeds is the reserve food-matter stored about the embryo to sustain it during and after germination till the seedling is well established on the soil and is capable of absorbing nourishment by its own roots and leaves. It may consist of (1) starch, (2) oil, (3) proteid, or any other form of reserve carbohydrate or nitrogenous matter. It is usually the endosperm, rarely the perisperm, and in a very few instances is composed of both. Thus, the white edible portion of the Cocoanut is endosperm; in Canna, the albumen is perisperm; in Lotus and the Pepper

the seed contains both endosperm and perisperm. The texture of the endosperm (or the albumen) varies in different cases. In the cereals, such as Wheat, Rice, Barley, and in all Grasses the endosperm is *farinaceous* or starchy. In Poppy, Castor-oil, Cocoanut, and generally in oily seeds the albumen is *oily*. It is hard or *horny* in the Betel-nut, Date and other Palms. Sometimes the inner seed-coat (*tegmen*) is folded into the endosperm, so that in a cross-section of the seed white zigzag streaks occur—*e.g.*, in Betel-nut, Custard-apple, and the Nutmeg. Such an endosperm is termed *ruminate*.

In **exalbuminous seeds** the embryo itself absorbs all the food-matter while it is being stored in the embryo-sac and by the time the seed is ripe the greatly enlarged embryo fills the whole cavity within the seed-coats. Inside the testa and tegmen there is only a large embryo and no trace of the nucellus is left. The embryo consists of two large fleshy cotyledons, a radicle, and a small plumule. The cotyledons store a large quantity of reserve food matter, such as starch, oil, etc., which nourishes the seedling during germination. All plants of the Pea (Gram, Bean, Pulses, Ground-nut, Tamarind, etc.), Cucumber (Gourd, Melon), Ipomœas, and Sunflower (Marigold, Zinnia) families have exalbuminous seeds.

Dispersion of seeds.—In order to enable seeds to propagate the species, the fruit which protects them during their period of growth and development must either scatter them or be itself scattered. Dehiscent fruits scatter their seeds; indehiscent fruits are often seed-like and scatter themselves. This dispersion of seeds and fruits is very necessary, for if, otherwise, all the seeds of a plant were to drop down and germinate directly below the parent plant, most of them will soon perish. For, in the first place, they will not find sufficient air and light, being shaded by the parent; secondly, the soil

must have been at least partially robbed of its nutritious things by the parent; thirdly the struggle for existence between so many plants, all huddled up in a poor soil and closed atmosphere, would be too keen. Hence plants try to scatter their seeds as widely as possible. The agents for such dispersal are (1) water, (2) wind, and (3) animals, while in many cases there are (4) mechanical contrivances for scattering the seeds.

1. **Dispersal by water.**—Some water-plants have floating arrangements in their fruits and seeds. Thus the fruit of Lotus has a spongy torus which floats in water and is carried away by currents when the stalk rots away. Eventually it bursts or disintegrates and the tiny seed-like fruits (achenes) come out of their sockets. In the Water-lilies (Shalook) the fruit bursts and discharges a quantity of gummy matter which holds the small seeds together and keeps them afloat; the seeds are also provided with a loose coat of aril. In plants living on the sea-coast similar floating devices in the fruit are often found. Thus the Coccanut, Betel-nut, and other Palms have water-tight coats which prevent the water reaching the inside, and a very light spongy mesocarp which helps the fruit for being carried by river or ocean-currents; the fruit may be carried by the sea hundreds of miles away. In virgin mid-sea islands the first plant-colonisers are those which have such floating devices in their fruits and seeds.

2. **Dispersal by winds.**—Wings on fruits and seeds making them extremely light for being easily blown over by wind are a common device. The samaras of Sal, Garjan Madhabi-lota, and the winged seeds of Parul, Sajina, Toona (*Cedrela*), etc., are instances. Fruits of many capitulas are provided with a hairy pappus (figs. 262-3). The segments of the pappus remain closed up when there is moisture in the atmosphere, but open out umbrella-fashion when

it is dry and windy. Such fruits are described as *parachute fruits* as they float away in the air like parachutes. Hairs such as those on the seeds of Akanda, Cotton, Silk-cotton, etc., make them very light, so that they are carried even by the gentlest breeze. Flying seeds or small fruits are found very commonly in the interior of forests where there is little chance of anything beyond wind to help the dispersal. The scattering action of the wind is not confined to a forward propagation only. Even in a calm sunny weather fruits and seeds provided with wings, hairs, and wooly coverings are carried up to a great height by the warm currents ascending from the hot ground, and thus are placed directly in the path of stronger breezes in the upper strata of the atmosphere.

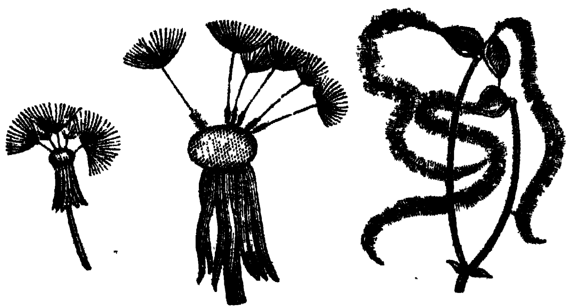


Fig. 262. Fig. 263. Fig. 264.

Fig. 262. Fruits of *Vernonia*. Fig. 263. Parachute fruits of a Compositæ. Fig. 264. Achenes of *Naravelia* with the persistent plumose style (only three shown in figure out of a dozen or more).

3. **Dispersal by animals.**—Many fruits and seeds are provided with hooks, burs or spines, or similar attaching organs whereby they stick to the bodies of birds and animals. Such fruits, however, are always small, inconspicuous and found amongst bushes or thickets. For instance, the common hedge-climber Chagal-bati (*Naravelia zeylanica*) and

the garden-climber *Clematis* have groups of achenes at the end of their stalks, each achene having a long hairy tail which is really the persistent style. Squirrels and such other animals running about the place entangle these tailed fruits in their body and thus carry them over a great distance. In meadows and fields tiny grass-fruits (Choar-kanta, Bena, Ulu, Kash, Koosh, etc.) often stick to our clothing by means of spines etc. Many aquatic plants produce seeds in such large profusion that they form extensive floating patches on the water. When ducks and waterfowls come in search of food, their body, especially the webbed foot, is smeared with the sticky seeds which are thus carried away from one pond to another.

It is, however, in the case of fleshy fruits that animals play the most-important role. Fleshy fruits are always sought when ripe, but are unwholesome or even poisonous so long as they are unripe. The seeds are often too hard to be crushed by the teeth (Guava), or have an unpleasant taste (Orange). Thus, while animals are invited by the soft nutritious pulp, provision is made to protect the seeds. When the testa is not hard, as in drupes of Mango, Peach, etc., there is a hard stony endocarp for protecting the seed. In berries and similar succulent fruits (Guava, Figs, Grapes) the number of seeds or seed-like fruits on the plant is very large, and this is meant to secure as many favourable chances as possible; some may be cracked or destroyed, but others escape destruction. Birds are the most common disseminators, for they can reach parts of plants inaccessible to other animals. They eat the edible pulp and the minute seeds or seed-like fruits adhere to their beaks, and even when devoured pass out with the excrement with the testa softened and the embryo ready for germination. As birds fly they wipe their beaks on the boughs, and the small seeds or fruits find a safe landing; they defecate too while

flying, and the indigestible fruits and seeds coming out with the dung fall on open land and thus secure the choicest place for germination.

4. **Dispersal by dehiscence.**—Many fruits burst their pericarp often with a sudden jerk and the *elastic force* is sufficient to scatter the seeds. Sometimes the bursting takes place with explosive violence and the seeds are ejected as if from a catapult, *e.g.* Balsams, (Dopaty), Oxalis, (Amrul), Shephalika. The fruit of the Dhundul (*Luffa pentandra*) when ripe breaks away from the stalk, and while falling ejects the seeds from the open mouth like shots from a pistol. Sometimes the valves of a capsule execute movements (Poppy) according as the atmosphere is damp or dry whereby they help the dispersion of the minute seeds. In dry weather the valves open out, in damp weather they shut up. Other dehiscent fruits have winged (*e.g.*, Sajina, Bignonias) or hairy (*e.g.*, Cotton, Akanda) seeds which are carried away by wind.

SUMMARY.

The **Seed** is the structure developed from the ovule after fertilisation. It consists of (*a*) the embryo, (*b*) the endosperm or albumen, and (*c*) the seed-coats. In some seeds the albumen is not present, hence called exalbuminous seeds, but the embryo has large fleshy cotyledons. The albumen consists mainly of starch, oil, or proteid matters, often a mixture of these. The testa or outer coat of the seed may be arillate, *i.e.*, with an aril; hairy, *i.e.*, covered with hairs; comose, *i.e.*, with a tuft of hairs; or winged.

Seeds and seed-like fruits (achenes, cypsela, samara, etc.) are dispersed by (1) wind, (2) water, (3) birds or other animals and human traffic, and (4) by explosive dehiscence of the pericarp.

1. Seeds dispersed by the wind are hairy (Cotton), comose (Akanda), or winged (Bignonias). Small fruits dispersed by the wind are samaras (Sal), or pappose cypsellas (Helichrysium, Vernonia).

2. Seeds dispersed by water often float by a spongy aril, or are held together by a jelly-like substance from the fruit (Water-lily). Some fruits float in water and are carried away by streams or ocean-currents, *e.g.*, Palms.

3. Seeds dispersed by birds stick to their beak which they wipe on the boughs of trees (Figs, Guava), and may even be devoured without injury, for they pass out with the dung and the acid fluid in the bird's stomach softens the testa of the seed and makes it easy for the embryo to come out during germination. Some seeds of fleshy fruits are very bitter and even poisonous, so they are never eaten (Orange).

4. Seeds of some plants such as Dopaty, Amrul, are jerked out with force when the fruit bursts.

QUESTIONS.

1. What is a seed? Trace the changes which take place in the ovule from pollination to the formation of the seed.

2. Distinguish between albuminous and exalbuminous seeds. Give a short account of the albumen of seeds.

3. Examine and describe the following seeds :—Castor-oil ; Poppy, Custard-apple, Sunflower, Pea, Tamarind, Mango, Cucumber, Rice, Mustard, Litchee, Jack, Bean.

4. Give an account of the various ways in which seeds are dispersed. Why are they so dispersed ?

PART II

INTERNAL MORPHOLOGY

ANATOMY OF PLANTS

CHAPTER XIII.

THE CELL.

A plant is made up of extremely minute chambers called cells (Kosh, *Sans*). They cannot be seen with the naked eye, but a microscope which magnifies small objects is necessary. If we strip off the skin from a young leaf or take a very thin slice from any part of a plant and see it under the microscope, we observe a structure resembling a honey-comb, made up of chambers very much like the chambers of a honey-comb. These are the cells. They are extremely minute bodies being actually no bigger than the hundredth or thousandth part of an inch. In some of the lower plants they are so small that they appear as mere specks or dots even when the microscope is magnifying a thousand times. Cells may, in a manner, be likened to the bricks of a building. Just as a a building is made up of bricks, so a plant is made up of cells, and just as in a building the bricks are variously grouped to form different structures, such as walls, pillars, arches, etc, so in a plant the cells are variously aggregated to form different tissues, such as the hard bony tissue, the soft nutritive tissue, and so on, which go to form the different parts, stem, root, leaf, etc. of a plant. Here, of course, the comparison stops, for plants are living bodies, so their components, the cells, are also living bodies, though most of them die in course of time and then form the permanent frame-work of a plant. The

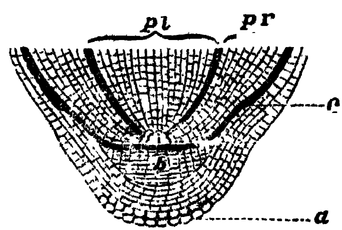


Fig 265. A thin slice of a young root, showing the cellular structure (magnified 40 times).

cells of a young growing plant, of any growing organ, are all living; those of the trunk of a tree are mostly dead.

Every plant begins life as a single cell—the fertilised ovum. The ovum is a female cell; it cannot grow unless united with the male cell developed from the pollen-tube. After this union, the fertilised ovum rapidly divides and forms from itself a number of cells. These also divide and grow, and place themselves in different groups so as to form the parts of the embryo. Thus the embryo is a *multicellular* structure which is gradually developed from a single cell—the fertilised ovum. After the embryo is formed it rests for a time, its cells lie dormant, until awakened to new life at the period of germination. From germination onwards the life of the plant is a ceaseless division and multiplication of cells followed by their growth in volume, and after maturity, by death. A plant thus consists of myriads of cells, some living, some dead. Some of the living cells continuously divide and produce new cells, others carry on the various nutritive processes, such as assimilation, conduction, and storage of food matters, while the dead cells merely act as protecting organs, such as the bark of a tree, or the spines, thorns, prickles, etc., or merely remove the waste or poisonous matters of a plant. Thus leaves are at first rapidly growing because their cells rapidly grow in volume, and then after preparing food matter in the soft green tissue and removing the same to the young buds and other growing parts, the cells die, the old leaf withers and then falls away.

The living substance of a plant is a jelly-like matter, called **protoplasm**, which resides inside a cell. It is like a drop of honey in the honey-comb of cells—a colourless, more or less transparent substance, though often it looks turbid or granular owing to the presence of minute particles of food-matter. It is this that lives, grows, and multiplies, while the wall, called the **cell-wall**, is a mere

secretion of the protoplasm. In the growing parts of a plant the cells contain a dense protoplasm and a very thin cell-wall; in a grown-up cell the protoplasm is thin but the cell-wall is prominent, while in an old dead cell the protoplasm is absent and the cell-wall is very thick. The old dead cells of the bark or wood of a plant does not contain protoplasm but only air or water. The ovum, the female cell, and the male cell of the pollen-tube, are merely masses of protoplasm without cell-wall. The fertilised ovum too is at first simply protoplasm, but after fertilisation gradually a cell-wall is secreted on the outside, and the walled cell thus formed divides and the daughter-cells again divide and so on; in this way the embryo is formed; the cells of the embryo have all cell-wall and protoplasm. Young living active cells have both protoplasm and cell-wall, dead cells have only cell-wall and no protoplasm, while the reproductive cells have no cell-wall but only protoplasm. The reproductive cells, the male and female cells, are called *naked* cells, because they have no cell-wall—they are naked protoplasts.

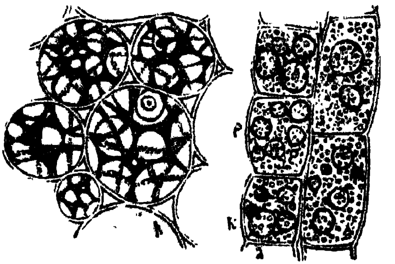


Fig. 266. Sections from the embryo (right) and a very young seedling (left) of Maize showing the cell-wall and protoplasm with its nucleus (magnified 240 times).

The protoplasm may be seen under the microscope by mounting a few threads of the green thread-like algæ, often found in ponds and ditches, in a drop of water on a glass slide. The magnified threads appear as rows of cylinders or barrels (fig. 267). These are the cells. The protoplasm is inside the cell-wall. The wall may be broken by roughly tearing the threads and then the protoplasm comes out as a stream of

frothy matter. The pollen-grains of flowers are also good objects. Each pollen-grain is a cell containing a dense protoplasm surrounded by a thick firm wall. The grains may be induced to burst by placing them in warm alcohol or glycerine when the protoplasm pours out as a highly granular slimy matter. The delicate root-hairs or branches of the root of Pistia (Pana, Beng.), Water-hyacinth, or any floating aquatic, may also be examined with advantage.

Protoplasm is a general term applied to the living contents of a cell. It is usually of a slimy semifluid consistency, although under certain circumstances, as in seeds and spores, it exists in a dormant state as a dense or tough mass. In all active cells, however, it contains a large percentage of water, and also other matters prepared by itself.

Being the fundamental basis of life the protoplasm has to perform all the varied functions of plant-life—nutrition, assimilation, secretion, reproduction, etc. Accordingly there are different *forms* of protoplasm, all differently constituted to carry on different tasks. The male plasma developed in a pollen-tube is distinguished as *spermatoplasm*, the female of the embryo-sac (ovum) as the *ooplasm*, that of a spore *sporoplasm* and so on.

Structure of the protoplasm. The protoplasm of a cell is usually differentiated into distinct layers each having a

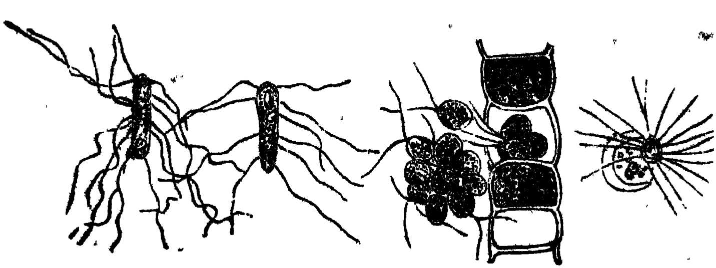


Fig. 267. Naked reproductive cells swimming in water with cilia. The first two are naked protoplasts with numerous cilia on the surface. The third figure is that of a filamentous alga composed of a row of cells; at the middle is a cell the wall of which has burst and the protoplasm is escaping as naked swimming cells.

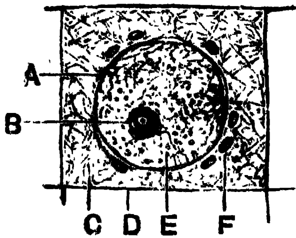
distinct form and function. In the naked reproductive cells of lower plants, there is an outer thin tenacious layer, the ectoplasm, which is almost transparent and completely invests a highly granular inner plasma, the endoplasm, the main body of the protoplasm. Imbedded in the endoplasm is a large, dense, highly refractive, spherical body termed the nucleoplasm or the nucleus. The ectoplasm is like a thin skin and serves to protect the inner more active plasma; it also often helps the cell to move about by throwing out whip-like projections, termed *cilia* (fig. 267) which lash in water and propel the whole body. The endoplasm is the actual nutritive field; its granular appearance is due to the presence of very minute drops of food-matter (metaplasm) which it partly manufactures and partly assimilates. The function of the nucleus is to guide the activity of the whole mass of plasma.

In all walled cells (fig. 268) the protoplasm is, as a rule, similarly differentiated into a central spherical highly refractive nucleoplasm or nucleus and a gelatinous ground substance. This part of the plasma (which surrounds the nucleus and fills up the cell) is the cell-plasma or cytoplasm. The structure of the cytoplasm is granular like that of the endoplasm, and the functions of the two are almost the same. But in addition the cytoplasm contains imbedeed in it numerous bigger granules, much smaller than the nucleus but, like it, highly refractive and dense, which under different circumstances become peculiarly coloured. These are known as the pigment-bearers or chromatophores. It is due to their presence that leaves are green, that flowers and other organs have all those exquisite shades of colour. *Nucleus, cytoplasm,* and *chromatophores* form the three primary differentiated parts of the protoplasm of all vegetative cells of a plant.

If a thin section from the growing part of a plant be

examined under the high power of a microscope, it will be observed that the constituent cells are densely aggregated,

Fig. 268. Fig. 269.



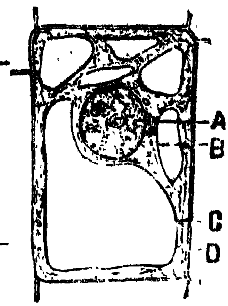


Fig. 268. A young cell from the growing point of a stem, (magnified 1000 times). A, nucleus; B, nucleolus; C, cytoplasm; D, cell-wall; E, chromatin; F, chromatophores.

Fig. 269. A growing cell showing the formation of vacuoles. A, nucleus: B, tonoplaim surroundsng C, a vacuole; D, cell-wall.

that they have very thin, transparent, almost invisible cell-walls, and that they are filled with a highly granular protoplasmic matter. The nucleus in each cell is large and occupies the whole centre (fig. 268. A). The chromatophores (F) appear as colourless granules imbedded in the cytoplasm and lying all about the nucleus. Sections taken a little lower down the growing tip of plants show an almost similar structure, but the cells here are much larger and the cytoplasm instead of filling up the whole cell-cavity develops cavities within itself, as shown in fig. 269. These cavities are called the *sap-cavities* or vacuoles and the liquid which fills them is called the cell-sap. As the cell grows it absorbs a large quantity of water, its cell-wall is greatly distended, and the cytoplasm becomes swollen and forms inside small cavities filled with water. Thus the cytoplasm of a grown-up cell is excavated or

vacuolated. In rapidly growing cells all the sap-cavities finally coalesce and form a large central vacuole (fig. 270). The cytoplasm never recedes from the cell-wall; even in very old cells which are all but dead, it forms a thin layer lining the inner surface of the cell-wall, and is then termed the *primordial utricle.* The nucleus lies always embedded in the cytoplasm; in old cells it becomes smaller. In a vacuolated cell it usually occupies a parietal position in the lining layer of the cytoplasm (fig. 270); but it may also have a central position, being then suspended in the vacuole by strands of cytoplasm running from the nucleus to the outer protoplasm, as shown in fig. 271; no part of the nucleus can be free from cytoplasm.

In young cells the cytoplasm surrounding the nucleus and filling the chamber of the cell is uniformly granular; it does not contain any prominent sap-cavities. In grown-up cells, especially in the vegetative cells of plants, the cytoplasm exhibits a further differentiation. The layer which lines the cell-wall generally is denser than the rest, is non-granular and hyaline, very much like the ectoplasm of naked cells. This layer is known as the **hyaloplasm.** Under the microscope it appears as a thin watery line separating the inner granular cytoplasm from the cell-wall. Another similar layer surrounds the vacuole and thus acts like a boundary line separating the contents of the vacuole from the outer granular cytoplasm. To this layer the term **tonoplasm** is applied; distinguished from these and lying between them is the middle layer of the cytoplasm which is called the **polioplasm.**

The meaning of this complex protoplasmic differentiation is this: The nucleus acts much like a storehouse of plasma-constituents and is perhaps also the seat of vital activities. It is the organic centre of the whole plasma, directing, guiding and controlling it, and is hence always

surrounded by the cytoplasm. The granular part of the cytoplasm is the actual laboratory of a cell; it is here that the protoplasm prepares and assimilates its food. The granules, called *metaplasm* or *microsomes*, are mostly matters in a very fine state of division; they are either the manufactured products of the protoplasm, or are food-substances in the course of being assimilated by it.

During the complex chemical changes which take place in the cytoplasm, food materials are absorbed and assimilated and some waste matters are also formed. The manufactured products are formed rapidly, so rapidly that they threaten to clog the cytoplasm unless speedily removed from the manufacturing centre. The *vacuole* then serves as a temporary storehouse of these manufactured products, chief amongst which are various kinds of sugars. The vacuole also serves as a storehouse of water, a tank from which the cytoplasm may draw supplies as required. It is necessary therefore to limit the vacuole by a denser hyaline layer, the *tonoplasm*, which prevents the cytoplasm being mixed up with the vacuolar waste-matters and also checks the overflow of the surplus products and water stored within it. Consequently the tonoplasm is a layer mounting guard over the vacuole and regulating the vacuolar pressure; it has a more or less protective function. The *hyaloplasm*, the external lining layer of the cytoplasm, is also protective and hence denser. It prevents on the one hand, too much friction of the delicate granular plasma with the rather solid cell-wall, and, on the other, allows the passage of water and only of those raw food matters which the protoplasm requires from the outside into the cell. These two hyaline layers, the hyaloplasm and the tonoplasm, are protective and are hence homogeneous and dense; they are not granular because they are not concerned with the task of assimilation or preparation of sugar or such things.

In contrast to these layers the middle granular plasma which has to prepare and assimilate food is called the *polioplasm*.

That the granular cytoplasm is the most active part is evidenced by the constant *movement of its particles* which may be observed in most cases. In the swimming naked cells mentioned above the endoplasm, which corresponds to the polioplasm of walled cells, is constantly changing its shape; a ceaseless streaming of the metaplasm granules takes place indicating a state of intense activity.

Almost similar movements may be observed in many vegetative cells of higher plants. The protoplasm in these cells being walled can not, however, move about bodily like the swimming primordial cells, but the constant change of configuration in the nucleus and the bigger granules evidences a similar unstability. In certain instances, moreover, the movement is very rapid; it looks as if a torrent has descended into a river and the muddy water flows along at a great velocity. To observe such a streaming movement take a leaf of the common aquatic *Vallisneria spiralis*, and get a rather thick longitudinal section; mount it in water and then observe under the microscope. The cells appear to have dark green contents and a large central vacuole, as shown in fig. 270. The protoplasm forms a parietal layer containing innumerable green bodies, termed chloroplasts, which more or less mask the true hyaline colourless basis of the cytoplasm. These green bodies, as well as a host of minuter granules, are seen to be moving in a steady and rapid stream in the cytoplasm. On the two sides of this stream, lining the cell-wall and the vacuole, there are clear watery non-granular layers of plasma in which the movement is not noticeable. These two layers are the hyaloplasm and the tonoplasm respectively.

The movement of the granular plasma in Vallisneria is known as **rotation**; it is common in most aquatic plants where the vacuole is large and occupies the whole centre of a mature cell. A similar rapid movement can be observed in the hairs of Cucumber and many other herbaceous plants. The protoplasm of these hairs does not form a strictly parietal layer but has thin plasma-strands going forth from

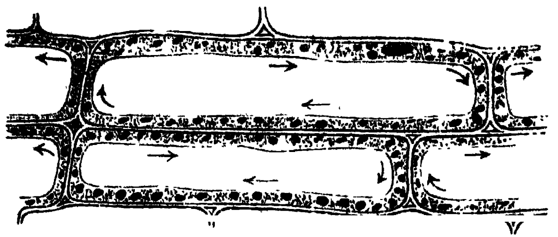


Fig. 270. Rotation in cells of Vallisneria—the dark bodies are the moving chloroplasts; the arrows indicate the direction of movement (magnified—400).

it, traversing the central vacuole and sometimes forming networks as shown in fig. 269. The movement of the granules is not regular and constant in direction, as in the last case, but is irregular. Granular currents often run in opposite directions, now uniting, now dividing, and give the impression of the movements of vehicular traffic in a crowded city. Such a movement is often referred to as **circulation**, the plasma-strands being supposed to circulate food matter throughout the cell, like the blood of animals.

The nucleus is the most important part of the protoplasm; it is the controlling centre of all protoplasmic activities. It takes the leading part in reproductive functions, in the formation of new cells from old ones. It is supposed to contain the hereditary substance, *i.e.*, it is through the nucleus that the hereditary characters are supposed to be transmitted to the successive generations. Possibly it is also the storehouse of all those things which are required from time to time by the cytoplasm for carrying on its various functions. As a rule there is one nucleus in one cell.

Structure of the nucleus:—In external appearance the nucleus looks like a punctated ball, somewhat like the

surface of an orange. It is surrounded on the outside by a clear and dense layer of plasma called the *nuclear membrane*.

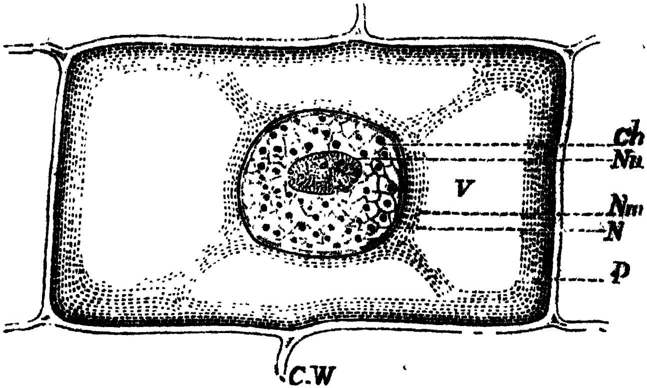


Fig. 271. A single cell from the skin of an Onion scale (magnified—1400). C, W, the cell-wall; P, cytoplasm; N, nucleus; Nm., nuclear membrane; Nu, nucleolus; Ch, chromatin granules imbedded in the network of linin; V, vacuole.

The mass of the nucleus is composed of a gelatinous ground substance of colourless threads the substance of which is termed the linin. The threads are intertwined and are connected to one another so as to form a complicated network in which lie embedded numerous globular refractive bodies called chromatin granules. One or more bigger bodies, the nucleoli (*sing.*, nucleolus) occur in this network. Numerous small cavities also appear; these are filled with a nuclear sap which sometimes circulates throughout the nuclear reticulum. The plan of construction of the nucleus is the same as that of the protoplasm. The corresponding parts are :—

PROTOPLASM		NUCLEUS
(a) Hyaloplasm (ectoplasm)	...	Nuclear membrane
(b) Cytoplasm ...	...	Linin
(c) Chromatophores ...	...	Chromatin
(d) Nucleus	...	Nucleolus
(e) Vacuoles ...	...	Nuclear sap-cavities
(f) Cell-sap ...	...	Nuclear sap

The chromatophores are called the pigment-bearers because they often develop pigments within their body and so become coloured. In very young cells, where they are located principally round the nucleus, they first appear as small, round or oval, colourless bodies. The pigments are developed later on in a well-grown cell under the influence of air and light. They are usually termed the plant-plastids, and according to the colour are of three kinds; *chloroplasts* (green), *chromoplasts* (red, yellow, or of some other colour), and *leucoplasts* (white).

(1) The *chloroplasts or chloroplastids* are the green chromatophores found in the green parts of plants *e.g.*, green stems and leaves. They consist essentially of a colourless plasma within which are developed drops of oily matter containing several pigments, of which a green pigment, known as *chlorophyll*, is the most important. The oily drops are known as *grana*; they decompose and become yellow in strong sun-light, also in old cells of withering organs.

The chloroplasts by virtue of their green colouring matter can absorb a portion of sunlight falling on the green leaves and stems, and, with the help of the energy thus derived from solar radiation, prepare organic substances, such as sugar and starch, out of the raw materials present in a green cell. They are the most important assimilatory organs of the plant, without them plants can not assimilate the raw matters absorbed from the soil and air. The green colouring matter (chlorophyll) is formed only in light, so that a plant kept in the dark soon dies. The chlorophyll can be easily extracted by alcohol by soaking green leaves in the liquid.

(2) The *chromoplasts* or *chromoplastids* occur in coloured parts of plants, such as the floral leaves, the skins of fruits, reddish skins of certain roots (Carrot) and underground stems, etc. They are coloured chromatophores, the usual shades of colour being yellow, red and orange. In shape they resemble the granules of chloroplasts but are usually smaller; sometimes their pigments occur in crystalline masses and this gives them a crystalline appearance.

(3) The *leucoplasts* or *leucoplastids* are colourless chromatophores found in cells in the interior of plants where light can not penetrate. They are specially abundant in the underground parts of plants, *e.g.* roots and underground stems, also in the interior of aerial stems. They are transformed into green chloroplasts when such parts are exposed to light; *e.g.* tubers of the Potato plant turn green when they become exposed to the air. Leucoplasts are specially concerned with the production of starch-grains; hence they are known as *starch-builders.*

To observe the structure of the protoplasm and the nucleus the following method may be followed. Take one of the inner white, fleshy scales of the Onion bulb, and peel off its skin by simply folding it into two and sharply drawing one piece against the other. The thin white skin thus obtained is at once put into alcohol and cut into small pieces. The alcohol 'fixes' the protoplasm, that is, kills it without destroying its structure. One piece is then washed in water and mounted in a drop of Iodine solution on a piece of glass slip. Under the microscope the section appears to be made up of innumerable rectangular chambers or cells. The central portion of each cell has a large deep yellow nucleus within which the dark dots of chromatin are apparent (see fig. 271). The nucleoli will be found to be most deeply stained and look like circular blots. The cytoplasm is of a light yellow colour and forms thin strings stretching from the nucleus in the centre to the layer lining the cell-wall. The nucleus is thus suspended in the centre of the cell cavity by cytoplasmic strands, as shown in fig. 271. Another piece is kept in Eosin solution for a minute and then thoroughly washed in water and mounted in a drop of glycerine. The nucleus is deep red, the cytoplasm is rose-red, while the nucleoli and the chromatin look like scarlet dots. Another piece may be placed in a mixture of equal

parts of a 1 per cent. solution of Iodine green and 1 per cent. solution of Fuchsin in water, for one or two minutes; then washed very thoroughly in water and alcohol, and finally mounted in glycerine. The cell contents show a very beautiful differential staining. The cytoplasm is rose red, its strings are pink, the nucleus is green, while the nucleolus is dark green or almost black.

Instead of the scales of onion, the young white roots of such floating aquatics as Pistia and the Water-hyacinth may be taken. The nucleus is clear and large in very young organs, and when such organs are transparent they are excellent materials for observation.

SUMMARY.

Protoplasm is the living substance of a plant. When active it is colourless, almost transparent, and somewhat viscid in consistence. It exists in various forms, but the protoplasm of an ordinary vegetative cell is usually differentiated into :—

1. **Cytoplasm**, the ground-substance of the cell-plasma, includes :—
   (a) *Hyaloplasm*—the outer hyaline layer of plasma in contact with cell-wall.
   (b) *Polioplasm*—the inner granular plasma, the granules *Metaplasm* being suspended in a clear plasma.
   (c) *Tonoplasm*—the thin hyaline layer surrounding vacuoles.
2. **Chromatophores**—the pigment-bearers. They may be :—
   (a) *Chloroplasts* or green : found in green parts of plants.
   (b) *Chromoplasts* or coloured red, yellow or orange : found in petals etc.
   (c) *Leucoplasts* or white : found in underground parts, and in the interior of stem.
3. **Nucleus**—the most refractive and the densest part of the protoplasm, consisting of :—
   (a) *Linin*—the hyaline fibres forming a net-work.
   (b) *Chromatin*—the granules imbedded in the linin network,
   (c) *Nucleolus*—the organic centre of the nucleus,

Every plant begins life as a single cell. This is the fertilised ovum. At the start this is a simple mass of plasma without cell-wall, and consists of a thin outer hyaline layer called *Ectoplasm*, the central nucleus, and the granular base called the *Endoplasm*. Gradually a cell-wall is secreted on the outside. The cell then divides many times and eventually a multicellular embryo is formed.

Every cell of the embryo contains a thin cell-wall and a dense protoplasm. As the cells grow they develop inside small chambers called *Sap cavities* containing a liquid called *Cell-sap*. In large grown up cells the protoplasm forms a layer lining the cell-wall and the sap-cavities all unite to form a large central chamber called the *Vacuole*. Further on, in a grown up tree, many cells lose their protoplasm and so become dead; these dead cells consist only of the cell-wall and contain sometimes certain other matters deposited by the protoplasm.

Young and active protoplasm shows a peculiar movement of its particles. The naked cells of Algae and Fungi rapidly move about like fish in water. In the walled cells of higher plants, the protoplasm shows running streams or currents in it. This movement (called cyclosis) is called, (1) *rotation* when there is a big vacuole and the stream goes round it parallel to the cell-wall, or (2) *Circulation* when there are cross-currents running through the vacuole as well.

QUESTIONS.

1. Describe a typical vegetative cell, illustrating your answer with a diagram. In what respects does a young cell differ from a very old one?

2. What is protoplasm? Where is it found in plants and what are its functions?

3. Give an account of the living contents of a cell, and the parts they play in the life of a plant.

4. Describe the following with reference to their (A) form, and (B) function: tonoplasm, metaplasm, cilia, cytoplasm, polioplasm, nucleus.

5. What are plant-plastids? Where are they found and what are their functions?

6. Describe some practical methods for observing the structure of protoplasm.

7. What is rotation of protoplasm? Describe an experiment you may have performed to observe this phenomenon.

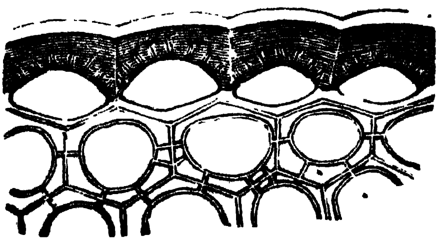
CHAPTER XIV.

THE CELL-WALL.

Its growth.—The cell-wall is a secretion of the protoplasm. It appears at first as a very thin skin which is permeable to water and extensible like a bladder. As the cell grows the vacuolar pressure more and more distends the delicate wall, but it is prevented from being ruptured by the addition of new particles of cell-wall substance secreted by the protoplasm. The *superficial* growth of the cell which thus takes place is due to the introduction of fresh particles from the protoplasm into the original thin membrane. This growth by *intussusception,* as it is called, appears to go on so long as the cell grows in volume. Along with this, thin layers of cell-wall substance are also deposited on the original thin membrane. This is called *growth by apposition.* So that growth in surface of the cell-wall goes on: (1) by the introduction of particles, and (2) by the deposition of layers of cell-wall substance. But when the cell has attained its maximum size, and no further growth in volume takes place, layer after layer of the cell-wall substance is deposited on the original membrane. This is called growth by *superposition.* In this way the cell-wall becomes thickened. Thickened cell-walls when examined under the microscope always exhibit a stratified appearance. The stratification (fig. 272) is due to the deposition of successive thickening layers; thicker denser layers alternate with thinner less dense ones.

Its structure.—Very young cells have a scarcely perceptible wall; it appears as a very thin, almost transparent, line limiting the protoplasm of one cell from that of a neighbouring cell. In mature cells the wall is commonly thickened, excessively so in certain thick-walled cells. In such a cell

three distinct layers may often be distinguished in the cell-wall. The original membrane upon which the successive depositions take place is the outermost,—it is the *primary* layer; the *tertiary* layer is that which faces the cavity of the cell, while the *secondary* layer lies between the two; the secondary layer is the most prominent and becomes variously modified and impregnated to give rise to cells of peculiar importance.



Stratifications in the thickened cell-wall.

Thickened cell-wall showing the primary, secondary, and tertiary layers with pits.

Fig. 272. Dead thick-walled cells from the outer skin of a plant.

The growth of the cell-wall is rarely uniform. This is especially the case in thickened cells. In them the secondary and tertiary layers are seldom applied all over the whole surface of the original membrane. For, during the thickening process the protoplasm takes care not to imprison itself within a thick wall, not to shut itself off completely from the outside whence supplies of food matter are coming. It usually leaves, from the very beginning, little spaces on the original cell-wall upon which the thickening layers are not applied; the spaces thus left vacant may in time rupture and form a narrow passage through which the protoplasm may escape, or the thin original membrane might allow the diffusion of water through it carrying food matters to the protoplasm. These spaces or small window-like spores are termed *pits*; they may be compared in a way to the cabin port-holes of a ship. Cells provided with pits are termed *pitted-cells* (fig. 272).

Pits are the unthickened areas of the cell-wall through which the protoplasm and other contents of adjoining cells

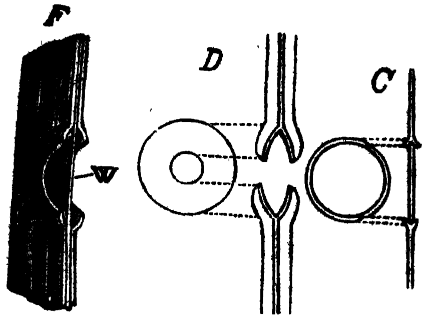


Fig. 273. Diagrams representing bordered pits. F, a thickened cell-wall common to two cells with two bordered-pits on two sides. W, the primary membrane left bare. D, the circles represent the inner and outer openings of the pits. C, shows the formation of the border.

communicate. The pits in adjoining cells coincide and are separated by the thin primary *closing-membrane* common to the two cells. In young cells this membrane has minute perforations through which fine threads of protoplasm (called *plasmodesma*) pass. In this way the protoplasm of one cell is in direct communication with that of another.

Simple pits are mere canals which penetrate the thickening layers of cell; they are circular or elliptical in outline. A special kind of pits, called **bordered pits**, is formed on certain long water-conducting cells (fig. 276-B). They are so called because the thickening layers are arched over the unthickened area of the primary membrane, so that the opening becomes contracted towards the interior of the cell. Seen from the surface a bordered pit appears as two concentric rings. The smaller inner ring represents the narrow opening of the pit facing the cell cavity, the larger outer ring corresponding to the margin of the primary unthick-

ened cell-wall (see fig. 273). In certain long conducting cells simple pits arise in such large numbers that the area of the cell-wall on which they occur appears perforated like a sieve. These pits are known as sieve-pits; the wall on which they occur is the sieve-plate; and the cells between which they establish inter-communication form sieve-tubes (fig. 275). The protoplasmic contents of sieve-tubes pass from one cell to another through these sieve-pits.

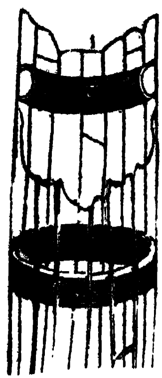


Fig. 274. An annular vessel, s, s, the thickened rings.

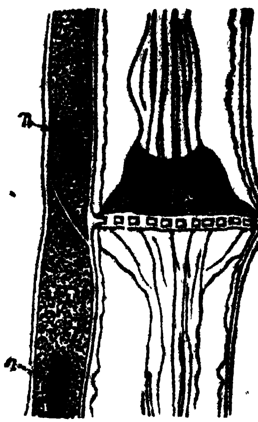


Fig. 275. A sieve-tube (to the right) showing the sieve-plate *sp*. with sieve-pits in the transverse membrane.

In certain long dead cells (fig. 276, C, E), the thickening layers are localised at certain parts only and leave wide gaps between them; the intervals are thin membranes. This happens because a great elongation of the cell takes place subsequent to the deposition of the secondary and tertiary layers, so that the unthickened parts are fully stretched out. The thickened layers are sometimes in the form of spiral bands, sometimes like closed rings (fig. 274), not unoften in parallel broken ridges like the rungs of a ladder (fig. 276, E), or forming net-works. The cells in which such

thickenings occur are usually arranged in rows or chains, the separating walls of which are thin and eventually vanish or break down, leaving a continuous passage through them. Such structures are termed **vessels**, and according to the peculiar form of thickening layers, there are *spiral*, *annular*, *scalariform* (ladder-like) and *reticulate* (net-work) vessels.

The cell-wall substance. Soft-walled living cells have their cell-walls made up of a substance called **cellulose.** The original thin membrane of a very young cell, however, contains but little of cellulose and is rich in *pectose*; but during the growth of a cell it is chiefly cellulose which is added to the cell-membrane. Cellulose is a substance allied to starch and sugar and is represented by the formula $(C_6 H_{10} O_5)n$; it forms the bulk of the cell-wall substance in all living cells.

In other cells the cell-wall often receives certain foreign matters in addition to the cellulose, or the cellulose itself is transformed. The most important of these substance are (*a*) *lignin*, (*b*) *cutin*, and (*c*) *suberin*. It is the secondary thickening layer which is more affected by these substances than the primary or the tertiary layers. In the spiral and other vessels mentioned above the thickening layers are impregnated with lignin; likewise in all hard dead cells which form the wood of plants. Such cells are termed *lignified* cells. *Suberised* cells, or those having their cell-walls charged with suberin, are found in the bark or skin of plants. Suberisation also occurs on the walls of pollen-grains. **Cutinised** cells, or those having their cell-walls impregnated with cutin, occur in the skin of most leaves.

A cell with a cellulose wall is pervious to water: the wall slightly swells with water and is collapsible. Lignification makes the cell-wall hard. A lignified cell-wall does not swell with water but allows the passage of water through its substance. Lignified cells are always dead cells; they merely serve to give rigidity to the plant, or act as pipes for

transporting water. Suberisation or cutinisation makes the cell-wall totally impervious to water. It takes place in those cells which are destined to act as protective skins.

In a few cases the cell-wall is impregnated with sand or silica or other inorganic mineral matter. It then becomes very hard and brittle. Such silicified cell-walls occur in the skins of many bamboo and grass leaves.

The cell-walls of Fungi are not of cellulose but consist of a substance, termed **chitin**, which is allied to suberin and shares some of its important characters.

In certain cells the cellulose is converted into a substance of a gummy nature, termed *gummose*, which swells and ultimately dissolves in water,—*e.g.* the testa of the seeds of Flax and Linseed. The cell-wall when dry is hard and horny, but absorbs water strongly to form a *mucilage*; hence such cell-walls are said to be mucilaginous.

Forms of cells.—Reproductive cells, as well as all isolated masses of protoplasm, are commonly spherical, oval, or more or less isodiametrical—*e.g.*, pollen-grains, spores of Ferns, the swimming naked spores of Algae and Fungi.

2. Young cells of growing points are usually like square or rectangular boxes; sometimes they are cylindrical, polygonal, or of similar form.

3. In some aquatics there are soft thin-walled star-shaped of *stellate cells.* They have cellulose walls and may contain either protoplasm or mucilaginous waste matters.

4. *Collenchymatous cells* form the collenchyma tissue which often occur just below the outer skin of soft herbaceous or rapidly growing stems of plants. They are living nutritive cells and contain protoplasmic matter, but have greatly thickened walls of cellulose, and are hence capable of considerable stretching.

5. In the hard shells and stones of fruits and seeds there commonly occur many cells of peculiar shapes, some like a star, some like a dumb-bell, and so forth, which serve

mechanical functions. They are termed sclerotic cells or scleroids. They have very strong, thick, lignified and hard walls. They do not contain any living matter and are hence dead cells.

Fig. 276. Typical prosenchymatous cells. A, a sclerenchyma fibre. B, a tracheid with bordered pits. C, a vasiform tracheid with spiral thickenings. D, a latex cell. E, a scalariform tracheid with ladder-like thickenings.

6. *Sclerenchymatous cells* are very long, narrow, pointed, fibre-like cells (fig. 276-A) with a very thick wall which is often lignified and hence hard, and have no living contents. They are dead cells and constitute the strengthening tissue, called the *sclerenchyma* tissue, of plants. The fibres of Jute

and Hemp and the choir of Palms, out of which ropes are made, are sclerenchyma. Their ends are drawn out into long narrow points, so that in the tissue which they form they are firmly interlocked as shown in fig. 295. Hence the long strings of fibres which we often get from plants rich in sclerenchyma are so strong that they can be twisted into cordage or ropes.

7. *Tracheids* are elongated thick-walled and lignified cells comparatively broader than the last. They are dead cells, contain no living matter, but are of great importance to the plant for they conduct water. Consequently they are often more or less full of water, especially in the young woody parts of plants of which they form important constituents. They are especially characterised by the presence of bordered-pits and other forms of thickening, such as *annular, spiral*, and *reticulate*, on their walls (fig. 276B).

The difference between tracheids and sclerenchyma fibres is this: tracheids are water-carriers, sclerenchyma fibres are only strengthening cells. The lumen or cavity of a sclerenchyma fibre is extremely narrow, that of a tracheid is much wider. Tracheids contain water, sclerenchyma fibres can rarely have anything as cell-contents except air. The sclerenchyma fibres are more or less solid and the thickening in their greatly thickened wall is almost uniform and uninterrupted, while in tracheids the wall is never uniformly thickened but contains numerous large pits which may be simple, elongated, or bordered, or special thickening layers. Sometimes very narrow diagonal pits are formed on the walls of the sclerenchyma, while in some very long and wide tracheids, termed vasiform tracheids (fig. 276C), annular, spiral, reticulate, or scalariform thickening layers are formed (see p. 182.) In contrast to these, narrow fibre-like tracheids are termed fibrous tracheids. The vasiform tracheids are the real water-

carriers; the fibrous tracheids are so narrow that they can not carry water, so they are very much like the sclerenchyma fibres and serve merely to strengthen or harden the wider tracheids. They, however, differ from the sclerenchyma fibres in certain respects: they are not so long as the fibres, and have blunt and not pointed or drawn out ends.

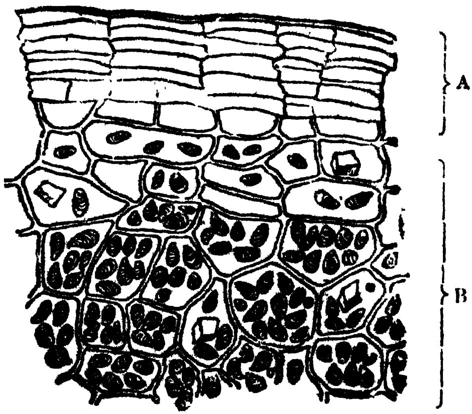


Fig. 277. Part of transverse section of a Potato tuber.

A. Dead suberised cork cells forming the outer brown skin.

B. Inner parenchymatous cells containing starch grains.

8. *Latex cells* or milk-cells are soft, thin-walled, greatly elongated cells which contain a milky or watery sap, called *latex*. They are commonly much-branched (fig. 276 D), the thin branches ramifying in many directions within the plant. They contain a thin layer of protoplasm lining their cellulose wall and an emulsion of various oily, gummy, or resinous matter forming the peculiar 'milk' or *latex*. They occur in plants which exude a milky juice when cut—*e.g.* Akanda, Papaya, Banyan, Fig.

9. *Cork cells* are rectangular or brick-shaped dead

cells (fig. 277 A), which do not contain anything save air. Their walls are strongly suberised and hence they are totally impervious to water. They occur on the surface of grown up parts of plants, such as old stem, root, fruit, etc., as a yellow or brown skin. Being impervious to water the skin forms a very safe protective layer which prevents the inner parts from losing water and drying up, or coming in contact with moisture and rotting. And, further, as the cells contain only air, they form also a good non-conducting layer protecting the plant from too great heat and cold.

10. *Wood cells* are box-shaped, thick-walled, dead, lignified cells which occur along with the tracheids in the wood of plants. They usually contain starch and help the tracheids in the conduction of water.

The various forms of cells given above are merely special forms of two main classes. These are :—

1. **Parenchymatous cells** which are thin-walled soft cells forming the tissues of plants. They are of various forms and may be living or dead, nutritive, protective, or secretory, and usually contain various cell-contents. Ordinarily, the portion of a plant which can be easily crushed out, say, with the pressure of the fingers, is parenchyma: such as the soft portion of the stem, root, leaf, flowers, fruits etc. They are distinguished from

2. **Prosenchymatous cells** which are elongated cells forming the bulk of the fibrous or woody tissues of plants. They may be thick-walled or thin-walled, may be lignified or not, and may or may not contain any living matter (figs. 274—276).

Cells exhibit the greatest diversity in form and hence it is not possible to classify them strictly from this stand-point. The several forms given above are not quite well defined, some coming under the description of parenchyma, some under

prosenchyma. Indeed the terms given above are with special reference to tissues, for, as a rule, similar cells are aggregated to form a tissue. The cells of collenchyma, wood, and cork are fundamentally parenchymatous; likewise the stellate cells. Similarly tracheids, latex cells, and those of sclerenchyma are typically prosenchymatous. See Chapter XVI.

Colour reactions of the cell-wall

Tests for the cell-wall.—Cellulose is commonly recognised by the test that it gives a blue colour when treated with Sulphuric acid followed by Iodine solution. To observe this, take cotton fibres or thin sections of the Date seed, Betel-nut, or of the endosperm of the seed of Cucumber, Gourd, Melon, Custard-apple, etc., with a razor. Put a few drops of Sulphuric acid slightly diluted with water on several sections, and after a minute or so, mount them in Iodine solution on a glass slide and cover the preparation with a cover-glass. Under the microscope, and even with the naked eye, the sections look a beautiful blue. Seen carefully, the cell-walls, when thick (as in Date-seed, Betel-nut, Custard-apple seed), show up the stratified blue layers alternating with whiter ones. The Sulphuric acid causes the cellulose walls to swell, and if sections are left long in the acid, they gradually dissolve. The blue layers which alternate with the whiter ones are those that are rich in cellulose matter; when greatly swollen, however, the cell-wall becomes uniformly blue and the stratified appearance is lost. Treated with Iodine solution alone, the stratification cannot be seen, for the layers which are pressed into a solid mass do not swell; the cell-wall is faintly yellow, if at all.

The blue colour with Iodine is the characteristic test of Starch. What happens when cellulose is treated with

Sulphuric acid is that the cellulose is converted into a substance related to starch, and this explains the blue colour with Iodine. If the sections be kept for a long time in the acid the cellulose is finally converted into sugar which gives no colour with Iodine. Hence in performing the last experiment care should be taken to see that the sections are not left too long in Sulphuric acid or that the acid is not too strong.

Another test is that with Chlorozinc-iodine (see appendix). Cellulose takes a violet or bluish colour. To observe this, sections are simply mounted in the reagent and examined under the Microscope.

A third is that it gradually dissolves in a strong Ammoniacal solution of Copper hydroxide (see appendix). To see this, take a few cotton fibres in a watch glass and pour enough of the reagent to cover it; observe from time to time that the fibres break up one by one and finally disappear.

The test for a lignified wall is that with (*a*) Iodine or (*b*) Aniline sulphate solution, it takes a golden yellow colour, and with (*c*) Chloro-zinc-iodine, it becomes deep yellow or even brown. In Sulphuric acid the wall swells and then gradually dissolves. With an acid solution of Phloroglucin it becomes deep red. To observe these reactions sections may be taken from a match stick, the cells of which are all lignified, or from the woody portion of any plant.

The test for a suberised or cutinised wall is that with (*a*) Iodine, (*b*) Chloro-zinc-iodine, or (*c*) Potash solution, it takes a deep yellow colour; (*d*) in Sulphuric acid it is *not dissolved*. Cutinised or suberised walls resist the action of acids very strongly, so that while strong Sulphuric acid will readily dissolve cellulose and even lignified walls, it will not affect a suberised or cutinised membrance. For

these reactions sections from the common bottle-cork or the bark of a tree may be taken.

For comparison, thin cross-sections of a hard stem, such as that of the Guava tree, may be mounted in: (*a*) Iodine solution, when only the outer cells (suberised) of the skin, and the inner lignified cells are turned yellow; (*b*) Chloro-zinc-iodine, when the suberised walls are brown, lignified cells are yellow, while those with cellulose walls become violet or pink; (*c*) Aniline chloride solution, when only the lignified cells are yellow; and (*d*) acid Phloroglucin solution, when only the lignified cells are red.

Mucilaginous cell-walls are easily known from their swelling greatly and forming a mucilage with water; they do not give any reaction with the above reagents.

SUMMARY.

The cell-wall is a secretion of the protoplasm. At first it is extremely thin. Gradually it grows and develops as it continuously receives matter to be added to its substance from the protoplasm. As it is greatly extensible, this matter is not only applied to its surface by the protoplasm but fine particles are also inserted into the cell-wall by the great pressure of the vacuole. Thus a young cell-wall grows both by *apposition* (as the former method is called) and by *intussusception* (the latter method). A grown up cell, however, is often thickened by the superposition of layer after layer of cell-wall substance upon it; this is growth by superposition. Hence a thickened cell shows *stratification* in its wall.

During the thickening of the cell-wall small spots remain unthickened and these form in the thickened cell fine pores called *pits*. Cells with numerous pits on its surface are called pitted cells. Pits are of various

forms, but the most important are (1) the *Sieve-pits*, formed in the wall of certain tubes called Sieve-tubes, and (2) *Bordered-pits*, formed in certain water-conducting cells called tracheids. In thick-walled cells pits are important for they are the openings through which the protoplasm receives food from the outside and also through which it may escape when necessary.

The substance of the cell-wall is mainly *cellulose*. This is a substance which is allied to, and can be easily converted into, starch. In a young cell, the wall is at first poor in cellulose but as the cell-wall grows more and more cellulose matter is added to it. Certain cells, however, have certain other matters in their cell-walls such as lignin, suberin, cutin etc, and such cells are called respectively *lignified*, *suberised*, *cutinised*, and so on. Cells with cell-walls of different composition behave differently. Thus cellulose walls absorb and swell in water, cutinised walls are impervious to water, and lignified walls transmit water but do not swell. Cellulose walls are soft and pliable, cutinised walls are tough and resistent, while lignified walls are hard and brittle. Suberised and lignified cells are as a rule dead cells; living cells have as a rule cellulose walls.

Cells are of various forms. Those that are formed singly, such as spores and pollen-grains, are spherical. Very young cells, like those that form the growing tips of roots, buds and branches, are cubical or cylindrical. In the mature parts of plants the cells grow up into many special forms. The main types are two: (1) elongated or *Prosenchymatous* cells and (2) iso-diametrical or *Parenchymatous* cells.

QUESTIONS

1. What is the cell-wall? How is it formed and how does it grow?

2. Explain how stratification arises in the cell-wall. Is it found in all cells?

3 What are pits and how do they arise?

4. Describe the various forms of Pits formed in cells.

5. What are bordered pits. Explain with the help of diagrams how they grow. Of what special significance are they to the plant?

6. Describe with diagrams the following :—

Tracheid, Sieve-tubes, Latex cell, Sclerenchyma, Scleroids, Sieve-plate, Spiral vessel, Stellate cells and cork cells.

7. Explain the composition of the cell-wall.

8. Distinguish between : (a) Lignified, (b) Cutinised, (c) Suberised, and (d) Mucilaginous cells.

9. How would you practically identify the above under the Microscope ?

10. Distinguish between Parenchymatous and Prosenchymatous cells, and name as many of their special forms as you can.

CHAPTER XV.

THE CONTENTS OF CELLS.

The protoplasm builds up the cells to form the framework of the plant. Old dead cells contain only air or water, but some cells store food matters prepared by the protoplasm or act as reservoirs of waste matters. Grown up cells of plants contain but little protoplasm but act as storehouses, while the protoplasm is rich in those cells in which the constructive activity of assimilation or growth is greatest. The cells of underground stems and roots, as well as those of fruits and seeds, contain various kinds of reserve food-matter chief amongst which are: (1) carbohydrates, (2) albumens, and (3) fats and oils.

Carbohydrates.

These are compounds of Carbon, Hydrogen and Oxygen, in which the hydrogen and oxygen are present in the same proportion as in water. When heated this water is soon driven out and the carbon alone is left behind as a black mass. The carbohydrates are—(1) the various kinds of sugars which are all soluble, (2) starch which is insoluble in cold water but dissolves in boiling water, and (3) cellulose, the substance which makes up the cell-wall of plants, totally insoluble in water.

Starch is the most important and common carbohydrate which is found as a reserve food matter in plants. Seeds often abound in starch which is required for sustaining the young embryo when they germinate. Underground stems and roots also contain a large store of starch. Tubers, fleshy rhizomes, corms, as well as all the cereal grains (*e.g.*

rice, wheat, maize, oats), and most pulses form the staple food of mankind because they contain the easily digestible carbohydrate starch.

Starch occurs in plants in the form of granules of various size which are first prepared by the chloroplasts in green leaves and stems. At this time the granules are very minute being enclosed by the small chloroplasts, but after a time they dissolve and are converted into sugar. The sugar dissolves in the cell-sap and the solution is then transported to the interior of the stem, to the underground parts, or to the seed and there it is reconverted into larger granules of starch by the leucoplasts. The leucoplasts are hence called starch-builders.

Fig. 278.

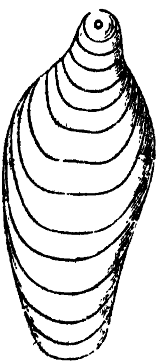


Fig. 279.

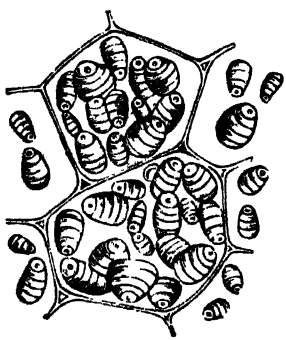


Fig. 280.

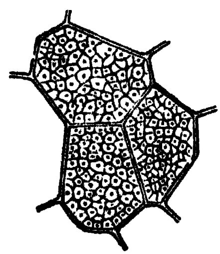


Fig. 278. A single starch-grain of Potato showing the *hilum* at the top as a small circle and the eccentric stratified layers (magnified × 750). Fig. 279. Section of Potato showing cells with starch grains. (× 250).

Fig. 280. Section of Rice grain showing cells containing the compound grains of starch (× 240.)

Structure.—A starch-grain has usually a *stratified* structure (fig. 278) ; as in the case of the cell-wall, thicker denser layers regularly alternate with thinner less dense

ones. Accordingly, when seen under the microscope with a high power lens, each grain exhibits alternating bluish and reddish zones or belts. The organic centre round which these layers are formed is termed the *hilum* : it is rich in water and appears of a reddish tint, and may be found either about the middle or at one end of the grain. Sometimes, as in Potato (fig. 278), the grains are *eccentric*, *i.e.*, the layers do not possess a common geometrical centre, the hilum being at one end ; in Wheat (fig. 282), Pea, Bean, and many pulses (fig. 281) the grains are *concentric*. They commonly occur as separate grains some of which are very large, as in Potato, Arrowroot and Canna. In other cases they do not form such *simple* grains but are compounded. *Compound grains* are merely aggregate of several grains firmly cohering to form a single

Fig. 281.

Fig. 282.

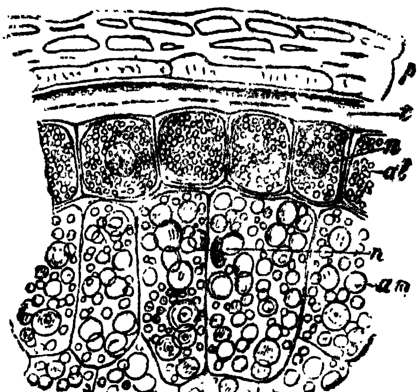


Fig. 281. Cells from the cotyledon of Pea showing the large concentric grains of starch and the innumerable small granules of aleurone.

Fig. 282. Part of a section of Wheat grain ; P, the pericarp composed of cork-cells ; t, the thin testa of the seed fused with the pericarp. The first layer of the endosperm tissue (n,al) contains minute amorphous aleurone-grains (al) ; these grains do not enclose globoids or crystalloids. The rest of the endosperm tissue lower down is full of starch-grains (am) ; n, the nucleus of the cell. (Both highly magnified).

body. The Rice starch shown in fig. 280 is compound, likewise that of Oats, each with some 100 to 300 minute grains. *Half-compound* grains arise by the union of two or more grains which then become enveloped by a few common layers (fig. 284). Both compound and half-compound grains can be observed in the cells of Potato along with the larger and more common simple grains.

In **chemical composition** starch has very much the same percentage composition as cellulose ; it is represented by the formula $(C_6 H_{10} O_5)_n$ where the value of (n) is indeterminate. The *test* for starch is that it takes a bright blue colour with Iodine solution, a colour which disappears at high temperature but again appears on cooling. In boiling water starch swells up and forms a paste which is then dissolved in excess of water to form a mucilage. When roasted, or on prolonged boiling, it becomes converted into dextrine, a kind of sugar ; hence the easy digestibility of roasted potatoes and other farinaceous vegetables.

Sugars are soluble carbohydrates. They occur in solution in the cell-sap. Starch and other insoluble carbohydrates, when transported from one part of the plant to another, are always first converted into sugar. The *cane-sugar* of the Sugar-cane and the Beet is a reserve carbohydrate like starch. Most fruits abound in what is known as the *fruit-sugar*, while *grape-sugar*, the sugar which we find in Grape juice, is the principal form in which carbohydrates travel in plants generally. Grape sugar is the simplest of the carbohydrates. It is first formed in the green cells of plants but becomes soon converted into starch.

Inulin is a kind of reserve sugar dissolved in the cell-sap of root-tubers of Dahlia, some Sunflowers, and other plants of the family. It is precipitated in the form of fine radiating crystals (fig. 285) when a section of the tuber is placed in alcohol or glycerine.

The carbohydrate **cellulose** is also sometimes stored as reserve food matter in place of starch. The Date seed, for instance, has very much thickened cell-walls which gradually dissolve on germination and nourish the young seedling. Similarly, the seed of the Betel-nut and other Palms, of Custard-apple and plants belonging to its

family, have reserve cellulose in the form of thick cell-walls. The seeds of Tamarind also have thickened cell-walls, not of cellulose but of amylose. The latter stains blue with Iodine like starch, whereas cellulose stains faint yellow. Inulin and other soluble carbohydrates are not stained with Iodine.

Albumens or Proteids

The **albumens** are nitrogenous organic substances of very complex composition containing Carbon, Hydrogen, Oxygen and Nitrogen, and also sometimes Sulphur and Phosphorous. They are also known as the **proteids**. In young cells where assimilation or growth is active the proteids are present in solution in the cell-sap, but in seeds and other reservoirs of food-matters the albumen condenses into fine granules termed **aleurone grains** (figs. 281, 282). In some cases, especially in oily seeds, some of the aleurone grains are very large and enclose angular plate-like or crystal-like bodies termed **crystalloids**. Sometimes also inorganic salts in the form of transparent beads are enclosed in a crystalloid or in an aleurone-grain; these are called **globoids**—chemically double phosphates of calcium and magnesium.

Aleurone-grains are present in almost all seeds, but they are particularly rich in oily seeds and sparse in those that contain starch. In Pea (Fig. 281) they may be seen as very small roundish grains lying in the same cells that contain starch. In Wheat (fig. 282) the first layer of cells that lie below the testa is full of small aleurone-grains, while the rest of the endosperm tissue is stuffed with starch-grains only.

Proteids are of various forms; some soluble in water, but the majority insoluble; some, however, are soluble in salt solution. They all give a deep yellow colour with Iodine solution. To see this take sections from Pea-seed and mount in Iodine solution and observe under the Microscope. The large starch grains stain blue, the smaller aleurone grains stain yellow (fig. 281). Treat other sections with dilute salt solution for some 15 minutes. Then wash in water and mount in Iodine solution. The cell-contents are only blue and the yellow grains are not there. This is because the aleurone grains are all dissolved out by the salt solution leaving alone the starch grains which turn blue with Iodine.

Crystalloids are found chiefly in the cells of oily seeds where they are invariably enclosed by the aleurone grains. To observe them take thin sections from the seeds of Castor-oil, Linseed, or some other oily seed. Mount in water and observe under the Microscope. The granular substance of the cells is partly dissolved and the crystalloids become all the more prominent. For, all crystalloids, unlike the aleurone-grains, are insoluble in water; generally they are colourless, except in petals and other floral parts where they may act as vehicles of colouring matter. Like all proteids they are stained deep yellow with Iodine.

Fats and Oils.

These are substances composed of carbon, hydrogen and oxygen but do not contain nitrogen like the proteids. They differ from carbohydrates in having the hydrogen and oxygen united not in the same proportion as in water. Usually they are poorer in oxygen than carbohydrates. They are insoluble in water or alcohol (except castor-oil) but soluble in either. In oily seeds (Poppy, Castor-oil, Mustard, Cotton, Cocoanut, etc.) where they are most abundant, they

Fig. 283.

Fig. 284.

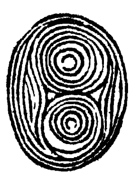


Fig. 285.

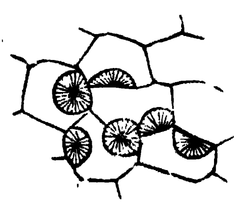


Fig. 286.

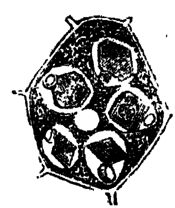


Fig. 283. A compound; fig. 284, a half-compound starch-grain.

Fig. 285. Inulin in cells of Dahlia-tuber precipitated as fine needles by Glycerine.

Fig. 286. A single cell from the endosperm of the Castor-oil seed showing the matrix of proteids with a few big aleurone-grains enclosing crystalloids with spherical globoids (highly magnified).

replace the carbohydrates but become converted into simpler and easily assimilable compounds when germination takes place, and hence must be regarded as reserve food matters.

Of all the vegetable oils found in plants, the fatty oils must be distinguished from the ethereal oils. Fatty oils are non-volatile and reserve food matters; they are found in seeds and may be obtained by pressure, *e. g.*—Castor-oil, Poppy-oil, Cocoanut-oil, Mustard-oil, etc.

Ethereal oils, which give the peculiar fragrance many flowers, fruits, and leaves have, are not reserve food. They are all very volatile and may be easily driven out of the cells by heat. Their function is not very well understood but perhaps they act principally for alluring insects, etc., for pollination and fruit-dispersion, for protecting plants from herbivorous animals or insect pests or disease germs, and so on. Oils of Turpentine, Eucalyptus, Orange, Lavender, etc., are examples.

Inorganic Crystals.

Besides the reserve food-matters described above various other matters are found in the cells of plants. These cell-contents are regarded as waste matters and include poisons, crystals, acids, pigments, mucilage and so on. They are formed in special cells which act in all respects as depositories of waste matter. Of these the crystals of Calcium salts occur rather widely in plants. Chemically they are either oxalate or carbonate of calcium.

Raphides are needle-like crystals of calcium oxalate which occur aggregated in bundles as shown in fig. 287. They

Fig 287. Fig. 288. Fig. 289.

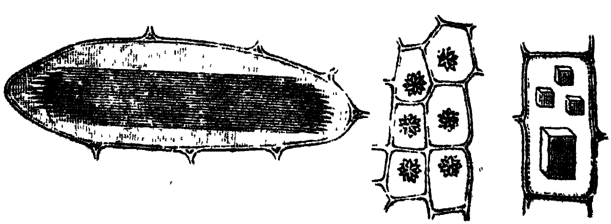


Fig. 287. A cell from the Water-hyacinth containing raphides imbedded in mucilage. Fig. 288. Sub-epidermal cells of Ol containing spherical clustered crystals of calcium oxalate. Fig. 289. A cell from Onion containing cubical crystals of calcium oxalate.

remain imbedded in the mucilaginous contents of certain cells and occur in many bulbs and underground stems, specially of small herbaceous Monocots. Octahedral or cubical crystals of calcium oxalate are also met with in old cells of many plants—*e. g.*, Onion, Begonias, Lemon, etc. Sometimes small crystals are so clustered that they appear to radiate from a common centre, as shown in fig. 288. These star-shaped crystals of calcium oxalate are called *sphærraphides.*

Less common are crystals of calcium carbonate which exist in extremely minute granules in the cells of certain plants. Unlike oxalate crystals, they are found more commonly as incrustations of the cell-wall. In many plants of the Banyan family, there are peculiar peg-shaped structures in some large cells below the skin of the leaf. These are swollen masses of the cell-well projecting inside the cavity of the cell, on which infinitely minute particles of calcium carbonate are deposited. Such a concretion is termed a **cystolith.**

To observe **Raphides** take thin sections from the inner soft parenchyma of the corm of Ol or Kachoo, and mount them in water; or even the juice squeezed out by lacerating the tissue may be taken. Under the Microscope myriads of fine needles will be found floating in the water. Some cells are especially rich in them With water the mucilage in which the needles are imbedded swells and so the crystals are liberated from their bundles. To observe the bundles undisturbed, sections from the leaf or stem of Water-hyacinth, Pistia, or Water-chestnut may be taken. The raphides will be found located only in a few spindle or torpedo-shaped cells which jut out in the large air spaces.

Sections taken from the thick outer skin of Ol or Kachoo reveal under the Microscope some of the most beautiful crystals. The crystals present a clustered appearance, somewhat like little globes of cut-glass (fig 288). Cubical crystals of calcium oxalate may be seen in sections from the scales of Onion (fig. 289).

To observe **cystoliths** take the leaf of the Indian Banyan, fold it several times so as to form a thick cushion and cut sections transversely. Mount in water or dilute Iodine solution and observe under the microscope. Just below the outer skin of the leaf will be found many large cells which contain dark spherical masses. Treated with a dilute solution of hydrochloric acid the masses clear up, evolving small bubbles

of gas (carbon dioxide), and then a peg-shaped structure is seen projecting into the cavity of the cell. On the surface of this minute crystals of calcium carbonate are deposited. Hydrochloric acid distinguishes crystals of calcium carbonate from those of the oxalate. The latter dissolve in the acid without evolution of gas. Another test is to treat sections with acetic acid ; crystals of calcium carbonate will dissolve with evolution of gas bubbles, whereas the oxalate crystals (raphides and other forms) are not dissolved.

The **cell-sap** holds various things in solution of which the sugars and certain organic acids are common. In coloured parts of plants the cell-sap contains a substance, called ***anthocyanin***, which under certain conditions becomes blue, viotet, red, etc, and to this is due the various colours of flowers, fruits, and foliage.

SUMMARY.

The contents of cells.—Young cells contain an active protoplasm, old grown up cells contain but little of protoplasm and a varying quantity of other matters manufactured by the protoplasm. The soft parenchyma of seeds, fruits, and swollen underground stems and roots contains a large quantity of reserve food-matters, chiefly starch and proteids, sometimes oils instead of starch, which are required for the future growth of new shoots etc. The cells of the bark or of the wood of a plant are mostly dead and contain only air or water. Certain other cells of a plant, however, store waste matters such as gums, resins, latex, ethereal oils, crystals, etc. The various kinds of cell-contents may be classified as follows :—

A. RESERVE FOOD MATTERS, stored in seeds, stems, roots, etc.—

1. ***Carbohydrates***, or non-nitrogenous food matters :—

(a) Soluble, present in cell-sap—the ***Sugars***, of which the most common is grape-sugar ; cane-sugar is found in the sugar-cane plant and the Beet ; fruit-sugar in many fruits. ***Inulin*** is present in some plants of Sunflower family.

(b) Insoluble, of which the most common and wide-spread is ***starch***, in a few seeds ***cellulose*** is present.

2. ***Proteids*** or nitrogenous food matters. These often occur as small granules called ***aleurone grains***. ***Crystalloids*** are crystallised proteids occuring in some large aleurone grains.

3. *Fatty Oils* are found in the cells of some seeds (Mustard Poppy, Cocoanut) instead of starch.

B. WASTE MATTERS, which are formed in certain cells of a plant, or in certain chambers or passages; rarely in seeds.—

1. *Crystals* which are generally of calcium oxalate, less commonly of calcium carbonate. Raphides are long needle-shaped crystals of calcium oxalate.

2. *Gums*, in such plants. Babla, Sajina, Ladies' finger.

3. *Resins*, as in Pines, Sal, Garjan, etc.

4. *Latex*, as in Poppy, Akanda, Figs, etc.

5. *Ethereal oils*, as in Lemon, Podina, Lavender, etc.

QUESTIONS.

2. What is starch? Where do you find it? Describe its formation and structure.

2. Distinguish between the contents of a green cell of a leaf and of the cell of a seed.

3. Describe the contents of a cell of the seeds of Pea, Wheat, Castor oil, Cucumber, and of Potato tuber.

4. Give an account of carbohydartes found in plants.

5. How would you distinguish starch grains from proteid grains? What are crystalloids?

6. Give an account of the important mineral deposits found in plants.

7. Give an account of the fats and oil found in plants.

8. Describe how you would proceed to demonstrate (*a*) Starch, (*b*) Raphides, (*c*) Cystolith, and (*d*) Crystalloids under the Microscope.

CHAPTER XVI.

THE TISSUES.

10 i

A **tissue** is a group of cells which together carry on a particular function of the plant. The body of the plant is made up of several tissues, each as a continuous aggregation of cells in intimate union. Tissues are the *internal organs* of a plant. Thus, there is a tissue for conducting water, the constituent cells being water-conducting tracheids ; a tissue for giving mechanical strength, the constituent cells being sclerenchyma fibres; a tissue for preparing food-matters (sugar, starch, etc.) the cells of which contain protoplasm with chloroplasts, and so on. A plant consists of myriads of cells, but all the cells are not doing the same kind of work, some are set apart for protecting the plant, some for absorbing food matter, some for assimilating them, some for conducting, some for storing, and so on. Cells which do different work are also structurally different ; thus conducting cells are elongated, nutritive or assimilating cells are living and have protoplasm, protective cells like those of cork are dead, and so forth. But cells which carry on the *same* function are quite alike in structure, and grow and develop in the same manner. A union of such cells which are similar in structure, growth, and function forms a tissue.

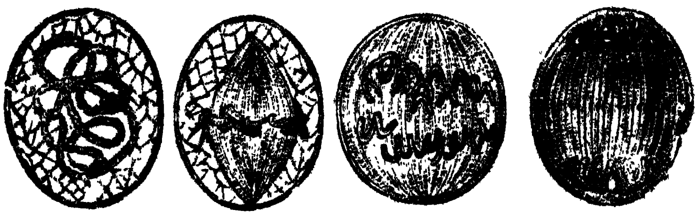
The soft green tissue of a leaf or young stem is a parenchyma containing chloroplasts in its cells ; it is hence called *chlorenchyma.* It prepares sugar, starch, and other food matters. The veins of leaves and their continuation in the stem constitute a *prosenchyma* tissue. They are made up of elongated tracheids and vessels which conduct water, sugar,

and other food-matters. The soft tissue of fruits, tubers, bulbs, rhizomes, corms, and fleshy roots, is a *parenchyma* which functions as a storage tissue; the constituent cells store starch or other food. The bark of a plant is a dead tissue composed of cork-cells; it is a protective tissue. So too the thinner skins of fruits, of underground and aerial stems, roots, etc.

All these tissues are grown up or mature tissues, *i.e.* their cells do not multiply or produce new cells. As opposed to these mature or permanent tissues, as they are called, there are other tissues which simply divide their cells. They only produce groups of cells which later give rise to the mature tissues. Such dividing tissues are called *formative* or meristematic tissues. For instance, the cells of an embryo are all rapidly dividing. They have very thin walls and a dense protoplasm which continuously divides, throws up partition walls, and thus new cells are formed. Later on, when the embryo has developed into a seedling, the tips of the root and the shoot are made up of cells which have only one task to perform, namely to divide. The growing tips of a plant, as well as all new formations, such as the buds in the leaf-axils and the rudiments of branch-roots, are all in an embryonic state; they are embryonic tissues or meristems. A meristem manufactures the cells which gradually grow up to form the mature tissues of a plant.

Cell-division.—The process by which the cell of an embryonic tissue divides itself into two cells is called *cell-division.* The first change which takes place in such a cell is that its nucleus gradually swells till its compact form is lost. By and by the linin thread becomes thicker and looser as shown in fig. 290 A. The nucleoli and the nuclear membrance disappear, so that the nuclear matter now floats freely in the cytoplasm. About this time, on two opposite sides, called the *poles*,

the cytoplasm is raised in the form of two caps so as to form a barrel-shaped structure. called the *nuclear spindle*.



A B C D

Fig. 290. Diagrams showing nuclear changes. A, the greatly swollen nucleus with its linin thread less entangled; B, formation of nuclear-spindle and chromosomes; C, separation of daughter chromosomes and their migration to the poles; D, formation of daughter nucleii by the reunion of daughter chromosomes and of the cell-plate in the middle of the cell.

Fine threads now appear in the cytoplasm and run from pole to pole and pass through the nuclear matter. The linin thread, with the chromatin granules ranged in parallel rows on it, now breaks up into a definite number of pieces called *chromosomes*. The chromosomes settle down in the middle of the spindle, and each is attached to some cytoplasmic threads which pass from pole to pole. These fibres then contract towards the poles and eventually split up each chromosome into two daughter chromosomes (fig. 291). The fibres go on contracting and drag the daughter chromosomes towards the two poles as shown in fig. 290C. In this way each pole receives exactly half the number of chromosomes. Next the daughter chromosomes of the two poles unite end to end, become entangled, and form the nuclear network of the two daughter nucleii. The cytoplasmic fibres then collect round them, gradually lose their fibrous nature and form the homogeneous cytoplasm of the two daughter cells. Between the two, in the middle of the parent cell,

granules of pectose matter are gradually developed and these eventually form a continuous *cell-plate*. In this way two daughter cells are formed from a single embryonic or meristematic cell. The daughter cells then grow, the thin pectose layer receives cellulose matter to form the resistant cell-wall, and after a short time the daughter cells divide in their turn. In this way a multi-cellular meristematic tissue arises which continually cuts off cells, some to grow up into mature permanent tissue, others to retain their meristematic character.

Fig. 291.

Diagram showing two chromosomes splitting into daughter chromosomes.

The structure of the growing point of a stem or a root is very simple. The tissue at the very tip is a meristem; it is made up of a number of cells which are all alike both in form and function. The cells are small, with a very thin cell-wall, and are full of a dense protoplasm. The nucleus is very large and fills almost the whole centre, while vacuoles or sap-cavities and starch and other granular matters are absent. Chromatophores are generally represented by small leucoplasts, less frequently by pale-green chloroplasts. The only function of the cells is to divide rapidly, and as the division of a cell is preceded by a division of the nucleus, the latter forms the most prominent part of the cell. This special meristem continuously prepares new cells. Of the tiers of cells cut off by the meristem, those that are at the top continue the meristematic character, while those of the lower tiers do not only divide but also grow up in volume and at last form the permanent tissues of the adult organ (stem or root). Below the growing point the cells are actively growing; they assume different forms, some long, some round, and so on; vacuoles appear, the wall is thickened, and other changes take place in the cells, and

thus new cell-aggregates or tissues are formed. Lower down the organ is fully differentiated; parenchyma, sclerenchyma, tracheids, and other tissues are formed. These are the permanent or fixed tissues, so called because they show no further *growth*, having attained their adult form permanently.

At the extreme tip of the growing points of lower plants including the Ferns, there is a single cell, called the **apical cell**, from which tiers of meristematic cells are cut off. The

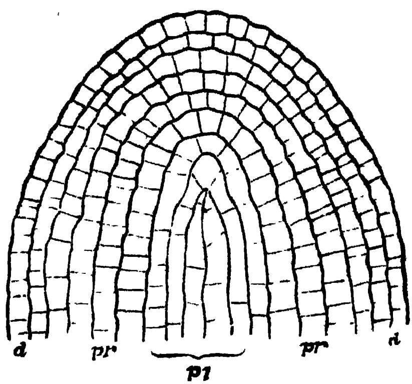


Fig. 292. Longitudinal section of the growing tip of a stem showing the three primary meristems :—d, the dermatogen ; Pr, the periblem ; Pl, the plerome.

growing points of higer plants (phanerogams) have, however, no apical cell but layers of meristematic tissue which constitute the **primary meristem.** Often, however, a small group of cells or even a single cell, corresponding to the apical cell of lower plants, can be found in the primary meristem. These are called the *initials* or the initial cells. They give rise to the primary meristem. The meristem which precedes the primary meristem is called the **primordial** or **promeristem**; from it all other meristems follow; the apical cell, and the initial cells are instances. New formations such as leaf buds and branch roots first arise as a group of

small actively dividing cells from the parent axis. These constitute the primordial meristem and later on, in the elongated stem or root, become more massive and constitute the primary meristem of the growing apex. The primary meristem is differentiated into three distinct layers of meristem. These are (fig. 292) :—

(1) The **dermatogen**, the outermost layer, passing right over apex and covering the other tissues like a mantle. Its cells divide only at right angles to the surface. It thus forms a single layer of cells which lower down form the **epidermis** or the outer skin of the plant. The dermatogen and the epidermis thus form a continuous layer covering the young organ, the dermatogen being at the top cutting off cells which lower down mature into the epidermis.

(2) The **plerome**, the central mass of cells of the growing apex. This can often be traced to a few initials (fig. 292). Its cells are slightly elongated and mostly divide by walls parallel to the surface. It produces below and is continuous with the central hard tissues of a plant which constitute what is called the **stele**. The stele forms the central cylinder of the plant and consists of elongated tissues which serve to conduct water and food matters.

(3) The **periblem**, the zone of meristem lying between the dermatogen on the outside and the plerome in the centre. Its cells divide in all directions, both by longitudinal and transverse walls at right angles to it. It produces below and is continuous with the soft parenchyma, called the **cortex**, which lies between the epidermis and the stele.

The dermatogen, the periblem, and the plerome are the three differentiated parts of the primary meristem. They produce the three adult primary tissue, the epidermis, the cortex, and the stele respectively. The epidermis is the tissue which forms the protective covering of a young organ; the cortex prepares and stores food matters, while the stele

serves to carry to and fro water and other food matters of the plant. Later on, in the older part of the stem, these simple primary tissues are further differentiated.

The primary meristem of the root differs slightly from that of the stem. The actual meristem lies a little behind the very tip of the root where there is the dead tissue of the root-cap. The outer older cells (*a*. fig. 293) of the root-cap are

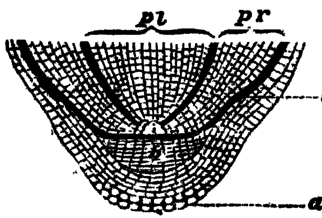


Fig. 293. Longitudinal section of the growing point of a root showing : a, the calyptra or root-cap ; b, the calyptrogen : c, the dermatogen ; i, initial cells ; Pr, the periblem ; Pl, plerome. The dark layer between Pl and Pr is the endodermis.

torn away as the root burrows through the soil, and newer cells are added from behind by the **calyptrogen** (*b*). This is the first layer of the primary meristem of the root. It divides its cells both inside and outside, those cut off on the outside going to form the root-cap or **calyptra**, while those on the inside form the dermatogen (*c*). A distinct dermatogen cannot, however, often be traced as it is merged in the calyptrogen. But further away from the tip a distinct root-epidermis, called the **epiblem**, is developed either from the dermatogen or from the calyptrogen. The periblem and the plerome of the root can often be traced to a single or a few initial cells, (i, Fig. 293) from which lower down they become clearly differentiated. These two meristems are separated by a distinct layer of close-packed cells which forms the inner limit of the periblem and later on develops into the endodermis separating the cortex from the stele.

Intercellular spaces.—These are spaces formed generally by the splitting of the common cell-wall of adjoining cells. They occur generally in some types of parenchyma, *e.g.* in the cortex of stems and roots, in the parenchyma of leaves, etc. The simplest intercellular spaces are triangular or quadrangular in outline (figs. 270, 271). In the cortex of stems and roots they are generally small and contain only air. Larger intercellular spaces containing air are found in leaves. They are especially abundant in water and marsh-plants and in floating leaves. Large air chambers or passages found in spongy tissues, such as in the petioles of Banana and water plants, are formed by a tearing or break-down of the walls of a group of cells. Such cavities or chambers are called *lysigenic* intercellular spaces as opposed to the ordinary *schizogenic* spaces formed by a mere splitting of the cell-wall.

In many plants long ducts or canals are formed which contain resins, gums, or other waste matters, as in Pines. These are intercellular spaces formed either lysigenously or schizogenously (see fig. 299 r), surrounded by special secreting cells called epithelium cells.

Kinds of tissues.—Tissues are primarily of two kinds: (1) multiplying or embryonic tissues, called meristematic tissues, and (2) fixed or permanent tissues which are fully grown up and differentiated tissues.

I. Meristematic tissues.—These are formative or dividing tissues composed of very small thin-walled cells with abundant cytoplasm and large nucleus. The different forms are :—

1. The *pro-meristem*, the original meristem of embryonal parts (embryo, buds, etc) from which all other meristems arise.

2. The *primary meristem* derived from the last, found at the growing points of stems and roots, and showing the preliminary differentiation into dermatogen, periblem, and plerome.

The *pro-cambium* is a part of the plerome; it is the meristem which later gives rise to the permanent conducting tissues of plants.

3. The *secondary meristem* originates from living permanent tissues which have already matured; certain cells of such a tissue undergo repeated cell-division and then resume meristematic activity. Two such meristems are well-known:—

(1) The *phellogen* or *cork-cambium* is a secondary meristem which arises in the outer cortex of a plant, just below the primary epidermis, to give rise to the cork or bark (fig. 294) of the plant. This cork tissue replaces the epidermis in old stems or forms a covering to wounds.

(2) The *cambium* is a meristem formed in the stele of a plant which continually produces the wood of the plant. It is due to its presence that Dicots and Pines increase continuously in thickness.

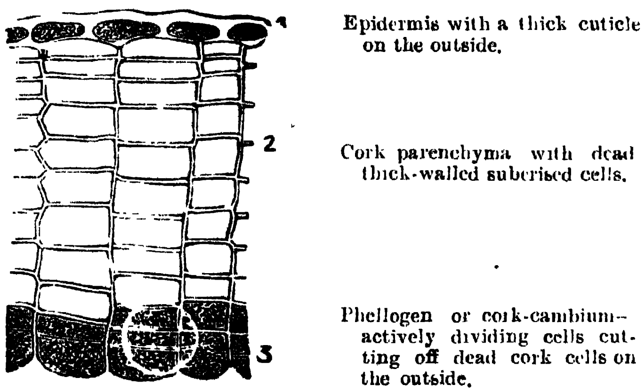


Fig. 294. Cross section of the bark of a stem.

II. **Permanent tissues** are the fully grown up adult tissues of a plant. They are derived from the primary or the secondary meristems, and hence in origin may be either

primary or secondary. They may be divided into three groups: parenchyma, prosenchyma, and vascular according to their form.

1. A parenchyma is typically a soft tissue with thin-walled cells which are more or less roundish or regular and generally have protoplasmic or other cell-contents. It forms the soft parts of a plant, of stems, roots, leaves, fruits, etc. Three special forms of parenchyma are:—

(1) *Chlorenchyma*, or the green parenchyma occuring in all green parts of a plant, the green colour being due to the presence of chloroplasts in the cell. This is the assimilating tissue of the plant; it prepares starch, sugar, proteid and other food matters.

(2) *Collenchyma* is also a green assimilating tissue like the last but it is mainly a strengthening tissue, for the cells have thick cellulose walls and can consequently be greatly stretched. It occurs in most rapidly growing herbaceous stems just below the epidermis (fig. 296).

Fig. 295.

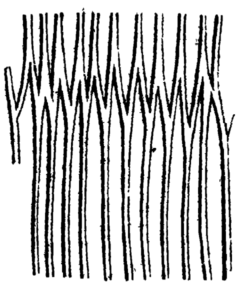


Fig. 296.

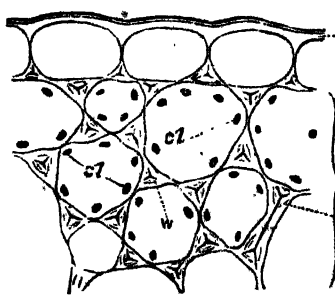


Fig. 295. A sclerenchyma tissue: the long fibrous pointed cells are interlocked (longitudinal section × 540).

Fig. 296. Outer part of a transverse section of a stem, showing E, the epidermis with c the cuticle, and ch, the collenchyma below the epidermis, W, the thickened cell-wall of the collenchyma-cells; cl, the chloroplasts (× 340).

(3) *Aerenchyma* is a very spongy parenchyma with large air-spaces which break up the tissue into strands or plates of cells. It constitutes the ventilating tissue of plants and is very prominent in water-plants.

The term parenchyma is applied generally to all soft tissues. It may have to perform various functions, such as assimilation, storage, secretion, etc. For instance, underground structures such as tuber, corm, rhizome, etc., and seeds which function as the store-house of nutritive matters, consist mainly of a colour-less parenchyma the cells of which contain starch, oil, or proteids; this storage tissue may be called a *storage-parenchyma*. The green chlorenchyma is essentially an assimilating parenchyma, the aerenchyma is the ventilating parenchyma, and so on. *Cork-parenchyma*, the brown tissue formed on the surface of potato tuber (fig. 277) and other underground and grown up aerial stems (*e.g.* of Guava) has a protective function; it consists of regular cubical cells which are full of air and have suberised walls, so that the tissue is impervious to water. A parenchyma which secretes waste matters such as gums, etc., as in Pines, Sal, and many other plants, is sometimes known as the *epithelial parenchyma*; it consists of thin-walled cells with living contents the function of which is to secrete waste matters.

2. A prosenchyma is typically a tissue composed of elongated cells. When the cells are thin-walled, they contain living matter along with the usual products of assimilation, such as sugars, proteids etc. which they carry from one part of the plant to another; when thick-walled they are often dead, hard, lignified cells, and contain only air or water. Two typical prosenchyma tissues are :—

1. *Sclerenchyma* or the strengthening tissue ; it consists of long fibre-like or spindle-shaped thick-walled cells (fig. 295) with pointed extremities so that they interlock into one another and thus form continuous strings running through the plant. It is a dead hard tissue which serves a mechanical function. The fibres derived from plants for textile purposes, as from Pine-apple and Agave leaves, Banana, Jute, etc, and those from Palms used for rope-making, are sclerenchyma.

2. *Tracheide* tissue is the water-conducting tissue of plants; it consists of tracheides (p. 185).

3. A vascular *tissue* or a *vessel* is formed by the fusion of cells. It is formed in this way: a row of elongated cells placed end to end become so firmly united that their transverse partition walls break down or become perforated by pits so that a continuous channel is formed. A vessel is a conducting tissue; water, sugar, proteids, and other matters formed during assimilation are rapidly transported from place to place through the vessels. The common vessels are:—

1. *Tracheae* or wood-vessels which conduct water. They are composed of thick-walled, lignified, wide tracheides placed lengthwise end to end and so united that the end-walls disappear or break down during growth. They may be: (*a*) simple pitted, (*b*) bordered pitted, or may have (*c*) spiral, (*d*) annular (fig. 274), or (*e*) reticulate bands of lignified thickening layers on their surface; (*f*) a scalariform vessel is one in which the surface bears elongated pits arranged in parallel rows so as to look like the rungs of a ladder.

2. *Sieve-tubes* are thin-walled vessels which conduct nitrogenous and other matters. They are composed of long thin cells with their common walls, especially the transverse septa, perforated by small pits termed sieve-pits, through which the heavier albuminous matters readily pass. So long as a sieve-tube is active its walls is lined with cytoplasm, and the pits are open, but in old sieve-tubes the pits are closed by a slimy matter called *callus* (see fig. 275).

3. *Latex-vessels* are formed by the fusion of a row of elongated thin-walled cells the end walls of which are absorbed. They conduct the *milk* or *latex* in some plants, *e.g.*, the Poppy, Mexican poppy, Papaw, etc. Such vessels as a rule ramify in all directions by sending side-branches which fuse at the ends when they come in contact.

SUMMARY.

Meristematic Tissue:

Primordeal or pro-meristem.

Primary meristems

Dermatogen	Periblem	Plerome
Epidermis.	Cortex.	Stele.

Primary Permanent Tissue: Epidermis. Cortex. Stele.

Permanent tissues

- Parenchyma
  - Green, living
    - Chlorenchma
    - Collenchyma
  - Colourless, living or not
    - Aerenchyma
    - Storage parenchyma, Cork parenchyma, Wood parenchyma, etc.
- Prosenchyma
  - THIN WALLED: Latex tissue
  - THICK WALLED
    - Scleren-chyma
    - Tracheide tissue
- Vascular tissue
  - THIN WALLED
    - Sieve vessel
    - Latex vessel
  - THICK WALLED: Tracheæ or Wood vessel

QUESTIONS.

1. What are tissues and how are they formed ? Name and describe some of the principal kinds of tissues.

2. What are meristematic tissues ? Describe the structure of the growing point of (1) a Dicot stem, and (2) a Dicot root.

3. Of what kind are the following tissues, and where do you find them ?--collenchyma, tracheide, latex vessel, procambium, phellogen, tracheæ; sieve-vessels, cork-parenchyma, plerome, calyptrogen, and sclerenchyma.

4. Distinguish between (a) a latex cell and a latex vessel, (b) tracheæ and tracheidés, (c) parenchyma and prosenchyma, (d) cambium and procambium, (e) pro-meristem and primary meristem.

5. Give a classification of the permanent tissues.

6. Describe tissues which serve (a) mechanical, (b) conducting, and (c) assimilating functions.

CHAPTER XVII.

PRIMARY TISSUES.

The **primary tissues** differentiated from the three primary meristems dermatogen, periblem, and plerome of the growing point are formed in young organs, such as stems and roots, and may now be studied in detail.

The **primary tissues in a young Dicot stem** may be easily observed under the microscope or with a high-power simple lens in thin transverse sections from the stem of a young plant (Pea, Gram, Sunflower, Balsam, etc) a little below the growing point. Fig. 297 shows such a section as seen under the microscope. The outermost layer of tissue forms the skin or the epidermis. It is composed of rectangular cells which fit closely so as to form a continuous layer. The

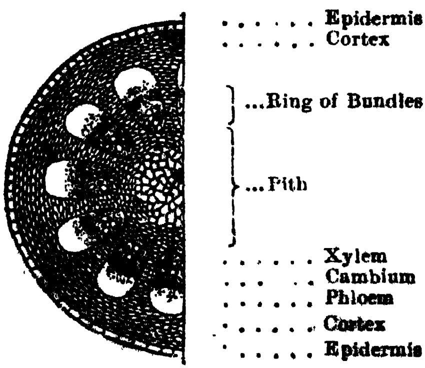


Fig. 297. Cross-section of a very young Dicot stem (Magnified × 50.)

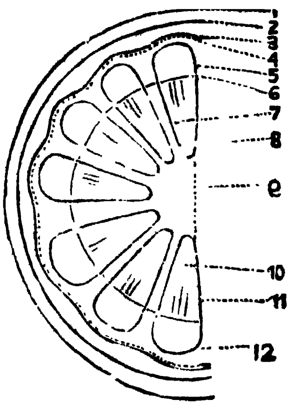
external cell-wall of this layer is slightly thickened and may be removed, especially lower down as a thin sheet called the *cuticle*. Below the epidermis comes a zone of many-layered parenchyma which constitutes the cortex. This is green owing

to the presence of chloroplasts in the cells. The inner layers of the cortex are colourless, and surround several wedge-shaped compact bodies called the bundles. These are arranged in a ring which forms the central cylinder or the stele. The core or middle part of this cylinder is a large-celled parenchyma called the *medulla* or *pith*. The bundles are separated from one another by strands of parenchyma running from the pith to the cortex: these strands are called ***medullary rays***.

What do these tissues do? The epidermis forms the outer covering and serves to protect the inner tissues from injury; for this purpose its outer wall is thickened to form the cuticle which becomes cutinised and impervious to water. The outer green cortex (chlorenchyma) is the assimilating tissue; it prepares starch and other food matters; the inner colourless cortex merely stores them. The bundles of the stele serve to conduct raw and prepared food matters to and from the assimilating tissue, also to carry water and other food to the growing apex of the stem, root, leaves and buds. The medullary rays serve as a channel of communication between the bundles on the one hand and the cortex and the pith on the other. When the amount of food matter prepared is more than can be stored in the cortex, the surplus passes through these rays to the pith to be collected there. The pith is also often the part where waste materials are stowed away. Also the water required by the cortex is drawn from the bundles by the medullary rays.

Excepting the bundles which are greatly elongated and so prosenchymatous in form, the whole mass of tissues enclosed by the epidermis is a soft parenchyma termed the fundamental tissue, so called because it is of the greatest importance and is the parent of all other tissues (secondary). Its parts carry on the assimilating, storage, mechanical and

other functions. In the Dicot stem the ring-like arrangement of the bundles divides the fundamental tissue into two parts; (1) that lying outside the ring of bundles is the *extra-stelar* and (2) that enclosed by the ring and forming part of the stele is the *intra-stelar* fundamental tissue.



1. Epidermis.
2. Outer cortex
3. Phlœoterma
4. Pericycle
5. Bundle
6. Cambium ring
7. Medullary rays
8. Proto-xylem
9. Pith
10 Xylem
11. Bundle
12 Phlœm

Fig. 298. Diagrammatic cross-section of a young Dicot stem.

The **extra-stelar fundamental tissue**, or the cortex, is often differentiated into three parts, though these are not very distinct in every young stem. Sections taken from a grown up herbaceous stem show that just below the epidermis there is a zone of green tissue the cells of which are thick-walled. This is the *collenchyma* (fig. 299 Co.) It is formed in all herbaceous Dicot stems which grow in length for a long time, annual stems for instance. The collenchyma serves not merely as the assimilating tissue but by virtue of its thick walls also gives the necessary rigidity to the soft stem to keep itself erect. This sub-epidermal portion of the fundamental tissue, called the *hypoderma*, is thus distinguishable from the inner softer parenchymatous cortex which may be partially green or entirely colourless. The

innermost layer of this cortex, that which immediately invests the stele, is often formed as a single layer of close-packed cells, very much like the epidermis, and is distinguished as a starch containing sheath or *Phloeoterma* (fig. 299 E). It is not well differentiated in aerial stems but in rhizomes and aquatic stems of Dicots it often forms a very firm and thick layer called the *endodermis* (p. 209).

The **intra-stelar fundamental tissue** or the parenchyma of the stele also consists of three parts: of these the medulla and the medullary rays have been mentioned. The other part which is conspicuous in such parts of the young stem which trail on the ground (in climbers, creepers, rhizomes, or trailing parts of the stem) is a zone of tissue just below the phloeoterma and surrounding the bundles. It is termed the *pericycle*; it forms the outermost layer of stele; beyond it lie the extra-stelar tissues. The pericycle is the seat of formation of young roots which always arise endogenously from the stem (adventitious roots). In erect stems it is sometimes present as a very thin layer with no particular task to perform, except sometimes as a well differentiated sclerenchyma to give rigidity to the stem, but very often its formation may be induced wherever there is the necessity of root-formation from the stem.

The **bundle** is the most complex of the tissues present in a plant. In a cross-section of the Dicot stem it is wedge-shaped in outline, and consists of two well-defined parts: one consisting of hard, lignified, thick-walled elements the cell-cavities of which are large and contain only water—this forms the inner half of the bundle and is called the *xylem*, and the other, the outer part of the bundle, consisting of soft thin-walled elements, the cells having a slimy protoplasmic content—this is called the *phloem*. The xylem is that part of the bundle through which water and raw food-matters in solution travel; the phloem is the part through which the assimilated products pass. Between the two lies a thin

white layer of meristematic tissue, called the *cambium*, made up of small, extremely thin-walled, actively dividing cells, which continually prepare new elements of the xylem and phloem on its two sides and thus increase the volume of the bundle. In a very young Dicot stem the bundles are small, in an old stem they enlarge, and so long as the plant lives the growth of the bundle runs apace.

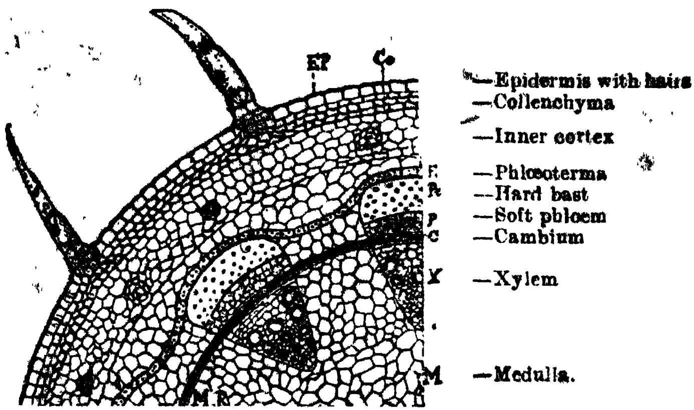


Fig. 299. Cross-section (one-fourth only) of a full grown Sunflower stem; Ep, epidermis with a thick cuticle on the outside and hairs; Co, collenchymatous hypoderma; r, resin passages surrounded by small epithelium cells; MR, medullary rays. (Magnified × 150).

Development of the bundle.—Each bundle is developed from a procambium strand of the plerome. During its differentiation the first formed xylem, called the *proto-xylem* and the first formed phloem, called the *proto-phloem* are formed on two opposite sides of the procambium, so that the proto-xylem lies nearest the axis of the stem at the apex of the wedge and the proto-phloem farthest away. From these points differentiation proceeds towards the central part of the procambium the cells of which gradually mature and

transform into hard lignified thick-walled elements near the axis, and soft thin-walled living elements together with fibres on the opposite side. The latter form the *meta-phloem* and the former the *meta-xylem*. The central part of the procambium, however, is not converted into a permanent tissue, but retains its meristematic character and forms the cambium. After the bundle is formed from the procambium, the cambium still continues to add new elements of phloem on the outside and new elements of xylem on its inside, so that gradually the first formed elements of the xylem and phloem, the proto-xylem and the proto-phloem, are pushed farther and farther apart. In a fully developed bundle the proto-xylem and proto-phloem cease to perform their function.

The **xylem** consists essentially of tracheides and tracheæ, the water-conducting tissues of plants, together with a thick-walled parenchyma, called xylem-parenchyma, the cells of which are at first living and supply the tracheal elements with the necessary food, but later lose their protoplasmic contents and simply store starch, sugar, and similar food-matter. The first formed elements of the xylem (proto-xylem) consists only of a few long spiral and annular tracheæ which are greatly stretched and may even be broken, for the young stem in which they are formed grows very fast. The metaxylem is composed of shorter and stronger elements; they are mostly pitted or reticulate vessels (tracheæ) and tracheides. Vessels and tracheides predominate in a young xylem, while wood-parenchyma is formed later by the activity of the cambium. (See fig. 300).

The **phloem** consists essentially of sieve-tubes, certain sister-cells of the sieve tubes called *companion cells* (see fig. 275, to the left of the wide sieve-tube are two narrow companion cells with nuclei *n*), and thin-walled fibres. The sieve-tube serves to conduct the protoplasmic and proteid materials, while the companion cell seems to help the sieve-tube to discharge

its function. The companion cell is so called because it is formed along with a sieve-tube cell from the same mother-cell of the procambium ; this mother-cell divides longitudinally into two, one becomes large and wide and goes to fuse with

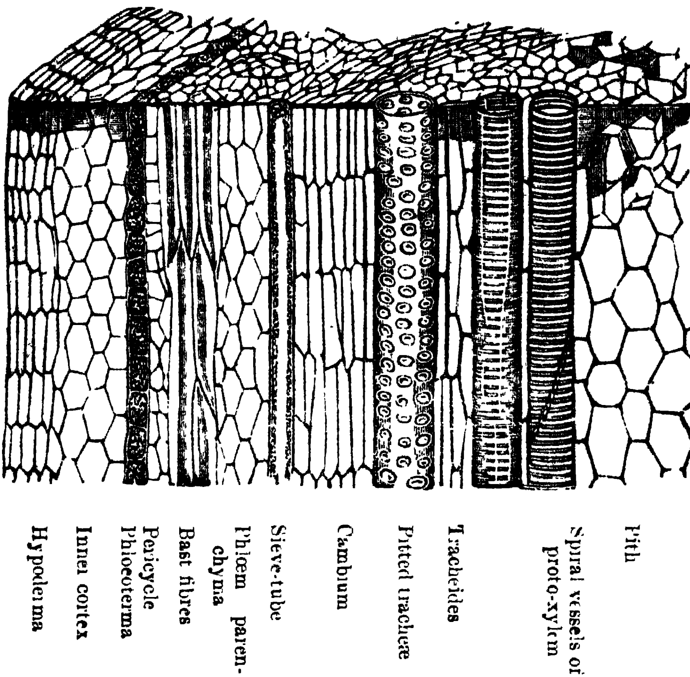


Fig. 300. Longitudinal section of a Dicot stem (part only).

the upper and lower cells similarly formed in the same row to form the sieve-tube, while the other remains as a narrow cell with abundant protoplasm and large nucleus—this is the companion cell. The sieve-tubes with their companion cells are the first formed elements of the phloem. They constitute the *proto-phloem* and carry the nitrogenous food-matter for the young organ, the carbohydrate food-matter being conducted by

the parenchyma lying about the bundle and in the xylem and phloem. Later on other sieve-tubes with their companion cells are differentiated, and also elongated phloem prosenchyma and parenchyma which are all thin-walled cells. In many cases in addition to these soft elements there are formed thick-walled fibres, called *bast-fibres*, in the phloem which serve to protect the tender *soft-phloem* from tearing stress. In Sun-flower (fig. 299) and other woody herbs the bast-fibres, or the *hard-bast* as they are collectively called, lie on the outside of the soft phloem or *soft-bast*. The bast-fibres are not present in very young stems but are fairly common in the adult organ, especially of climbers and annuals (Jute, Hemp). They are very long spindle-shaped cells with a thick wall of cellulose which in many cases become lignified and hard.

The following is a summary of the tissue-elements present in the primary Dicot bundle.--

1. **Xylem,** near the centre of the stem or the medulla—
   1. PROTOXYLEM, occupying the apex of the bundle, nearest the medulla, consisting of spiral or annular tracheæ.
   2. METAXYLEM, the rest of the xylem, consisting of
      (a). *Vessels* or tracheæ, pitted, reticulate etc.
      (b). *Tracheides*, vasiform or fibrous.
      (c). *Parenchyma*, small regular cells.
2. **Phloem,** towards the cortex—
   1. PROTOPHLOEM, consisting of narrow sieve-tubes and companion cells.
   2. METAPHLOEM, the rest of the phloem, consisting of
      (a). Wide *sieve-tubes* with
      (b). *Companion cells* and other elongated cells.
      (c). *Bast fibres* or thick-walled elongated cells which constitute the hard-bast, the other parts of the phlœm being *soft bast*.

3. **Cambium,** the meristematic tissue lying between the xylem and phloem, consisting of row of small thin-walled regular actively dividing cells.

The primary tissue of a young Dicot stem may be summarised as below.—

- Dermatogen
  - Epidermis
- Periblem
  - Cortex, or Extra stelar tissues.
    - Hypoderma (Collenchyma)
    - Cortex proper
    - Phlœoterma
- Plerome
  - Stele
    - Intra stelar tissues.
      - Pericycle.
      - Medullary rays.
      - Medulla.
    - Bundle.
      - Xylem
        - Proxylem.
          - Spiral vessels
          - Annular vessels
        - Metaxylem.
          - Other vessels
          - Tracheides
      - Cambium
      - Phloem.
        - Protophloem
          - Sieve-tubes.
          - Companion cells.
        - Metaphloem
          - Phloem-parenchyma.
          - Bast fibres.

The primary tissues of a Monocot stem may be observed in a thin transverse section of a young Grass stem or that of any herbaceous Monocot. The epidermis forms a continuous layer of rectangular cells with a cuticle on the outside as in Dicots, but the arrangement of the other tissues is very different. The bundles are *scattered* in the ground tissue, not in a ring as in Dicots; they are also not wedge-shaped as in Dicots but have an oval outline in cross-section. Owing to the scattered arrangement a well-defined pit is not seen, and the intra-stelar and extra-stelar fundamental tissues cannot be distinguished; neither can the medullary rays. (See fig. 301.)

Below the epidermis lies the cortex; this is not a uniformly soft parenchyma but consists of isolated strands of sclerenchyma separated by patches of green parenchyma. The reason why the hypodermal sclerenchyma is formed in the Monocot stem and not as a rule in Dicots is that the latter soon form a continuous ring of hard wood through the activity of the cambium and this wood enables the stem to remain erect, whereas in Monocots there is no cambium in the bundles and so the wood is not formed and the stem can

only be made stiff with the help of mechanical or strengthening tissues—these are the sclerenchyma strands.

The cortex forms a very thin zone ; inwards it merges into the large-celled parenchyma of the stele, and the bundles are found scattered far in the hypodermal region. This is because the stele of the Monocot stem forms a very wide cylinder, stretching so far out as the outer tissues, so that the cortex is comparatively a thin zone. A phlœoterma is not distinguishable, and so too the pericycle of the stele, though in the trailing or lower part of the stem a ring

Fig. 301.

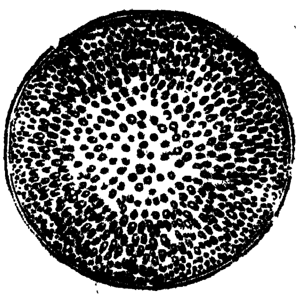


Fig. 302.

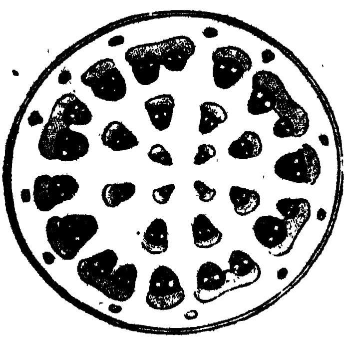


Fig 301. Cross-section of a typical Monocot stem showing the scattered arrangement of the numerous bundles. Fig. 302. Cross-section of a Palm-stem showing the bundles arranged in several concentric rings. Note the sclerenchyma patches in the outer cortex.

of tissue may be seen surrounding the region of the bundles. From this ring adventitious roots first begin to develop.

The stele is differentiated from the plerome as in Dicots. The procambium strands develop into bundles which are often present in large numbers; they are scattered in the ground tissue and hence do not enclose a well-defined pith, nor are the medullary-rays differentiated. The pericycle, however, is present, but is not often distinguishable from the

ground tissue in which it is merged, though in some cases it is developed as a ring of sclerenchyma.

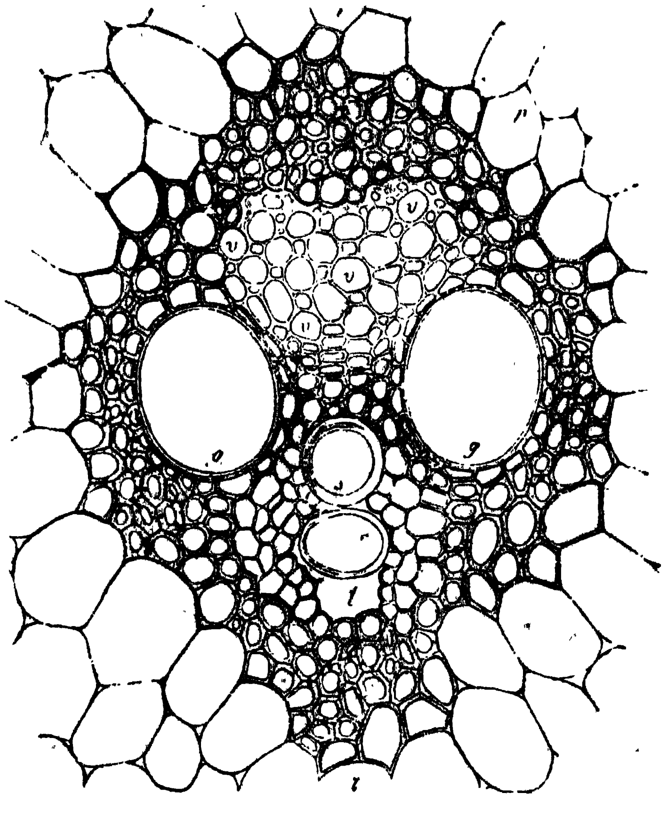


Fig. 303. Cross-section of a Monocot bundle (highly magnified). The bundle consists of xylem (g. g. s. r. l.), phloem (v. v. v.), and the sclerenchymatous bundle-sheath (the thick-walled cells) surrounding the xylem and phloem, p, thin-walled parenchyma of fundamental tissue. The xylem consists of: g, g, two large pitted vessels; s, spirally thickened vessel; r, annular vessel; l, an air containing cavity, and the smaller xylem parenchyma. The phloem consists of v, v, the sieve-tubes, and the smaller companion cells near them.

Each bundle consists of xylem facing the centre of the stem and phloem facing the cortex, but the Monocot bundle differs from the Dicot bundle in many points. In the *first place* there is no cambium, so that a bundle once fully differentiated from a procambium strand cannot grow subsequently. Such a bundle is said to be closed, as opposed to the Dicot bundle which possesses cambium and is hence called open. Year after year new xylem and new phloem are formed by the cambium of the open Dicot bundle, so that it grows continuously, but the closed Monocot bundle cannot grow further. It is for this that Dicot stems continually grow in thickness; Monocot stems do not do so, they are columnar or cylindrical throughout. And *secondly*, each bundle is more or less surrounded by a thick sheath of thick-walled fibres or sclerenchyma (fig. 303)—this is called the *bundle-sheath.* This sclerenchymatous bundle-sheath is a characteristic of the Monocot bundle. It serves not only to support the delicate tissues of the bundle, but also forms, along with the hypodermal sclerenchyma, the system of mechanical tissues which makes the plant rigid. Such a sclerenchyma-sheath is absent in the Dicot bundle for obvious reasons. The Dicot bundle grows continuously in thickness, so a rigid sheath like that of the Monocot bundle would be of little use and would soon be ruptured, if present, and further the cambium itself produces, along with the conducting elements of the bundle, some fibres, such as the bast fibres of the phloem and the fibrous tracheides of the xylem, which act as the strengthening tissue.

The xylem of the Monocot bundle is V-shaped in cross-section. The apex of the V is turned towards the centre of the stem and is occupied by a few spiral and annular vessels or tracheæ. These constitute the *proto-xylem*, while the *meta-xylem* occupies the two arms of the V. The first formed vessels of the proto-xylem is often torn during growth so that a large intercellular space (lysigenic, p. 210) is found

at this part. Each arm of the V is marked by a single very wide vessel with spiral or reticulate thickenings. Between the two arms lie several narrow vessels and tracheides (in most Grasses), or simply the phloem (in many Monocots).

The phloem lies either between the two arms of the xylem or a little away from it. It forms a comparatively small roundish patch, and consists almost entirely of sieve-tubes with their companion cells.

The following table gives a comparison of the primary tissues of young Dicot and Monocot stems.—

Dicot Stem.	Monocot Stem.
1. EPIDERMIS, a single layer, with cuticle on the outside.	1. EPIDERMIS, a single layer with cuticle on the outside
2. CORTEX, a very wide zone, consisting of— A. An outer collenchyma B. Thin-walled green parenchyma C. Innermost layer of phlœoterma	2. CORTEX, a thin zone, consisting of— A. Outer sclerenchyma bundles B. Thin-walled green parenchyma merged into the colourless stelar parenchyma.
3. STELE with bundles arranged in a ring, consisting of A. A ring of pericycle on the outside B. A medulla in the centre C. Medullary rays between the bundles	3. STELE with bundles scattered in the ground tissue, with A. Pericycle not very distinct B. Medulla not distinct C. Medullary rays not present
4. Bundles, wedge-shaped, open A. Xylem B. Phloem C. Cambium	4. BUNDLES, cylindrical, closed A. Xylem B. Phlœm C. Vascular bundle-sheath

The bundles of the stele are called **vascular bundles** because they consist mostly of vascular tissues and so must be distinguished from the sclerenchyma bundles which are often found in the cortex. The vascular tissues of a bundle are, however, often associated with fibrous cells, as the bast fibres of the phloem and the fibrous tracheides of the xylem in the Dicot bundle and the fibrous bundle-sheath of the Monocot bundle, and hence a vascular bundle is also called a **fibro-vascular bundle.** Such a bundle is not a simple tissue, but is made up of several tissues : (1) the tracheide and tracheae constitute the conduct-

ing tissues for water and raw food-matters taken from the soil, (2) the sieve-tubes and companion cells conduct chiefly the nitrogenous matters prepared by the plant, and (3) the fibrous elements serve to strengthen the bundles and the plant. The following scheme is an analysis of the main constituents of the bundles.

Dicot bundle.

- Fibro-vascular bundle.
  - Conducting tissue.
    - Sieve-tubes
    - Companion cells
    - Parenchyma
  - Mechanical tissue.
    - Bast-fibres
    - Wood-fibres
  - Conducting tissue.
    - Parenchyma
    - Spiral, Annular
    - Reticulate vessels
    - Tracheides
  - Cambium

Phloem: Sieve-tubes, Companion cells, Parenchyma, Bast-fibres.
Xylem: Wood-fibres, Parenchyma, Spiral, Annular, Reticulate vessels, Tracheides.

Monocot bundle.

- Fibro-vascular bundle
  - Conducting tissue.
    - Sieve-tubes
    - Companion cells
    - Spiral
    - Annular
    - Reticulate vessels
    - Tracheides.
  - Mechanical tissue.
    - Sclerenchyma bundle-sheath

The Primary tissue of a Dicot root may be seen in cross-section of a young root. The three primary tissues, the epidermis, the cortex, and the stele are derived from the three primary meristems as in the stem. But the epidermis here is not a protective layer as in the stem; it is an absorbing tissue, and is often called the *epiblem*. The cells contain a thick lining layer of protoplasm. Their walls are of thin cellulose membrane and readily absorb water from the soil. Here and there cells are drawn out into long tubes called root-hairs, hence the layer is also called the *piliferous layer* (see fig. 305). The root-hairs serve to increase the absorbing surface of the root. The epiblem is only short-lived.

It persists only in the young root, at the region of the root-hairs; and as the root elongates the older hairs die off as new ones are formed towards the tip, and so the epiblem is torn away in the older part of the root.

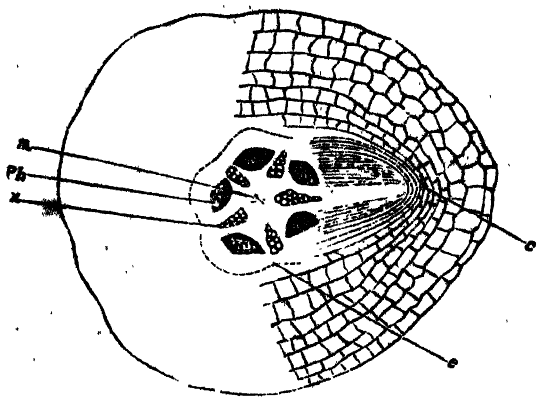


Fig. 304. Transverse section of root of the Bean showing origin of lateral root from the pericycle. c, the primary meristem of the embryo-rootlet; e, endodermis; m, central parenchyma, ph, phloem; x, xylem.

Below the epiblem is the zone of cortex. The cells, like those of the epiblem, have thin cellulose walls lined by protoplasm. In the outer layers the cells are in close contact but intercellular spaces are present more internally. In the older part of the root, a little away from the region of root-hairs, the outermost layer of the cortex continues for some-time to produce hairs for absorption and thus becomes piliferous. But this too is short-lived, the outer cells are torn away as the root pierces the soil, and then the cortex forms on the outside a firm layer of cells which acts like the root-epidermis and is called the **exodermis**. It may also become suberised and form a continuous protective layer impervious to

water. The inner layers of the cortex become gradually large-celled towards the stele and enclose bigger intercellular spaces. The innermost layer of the cortex, that which

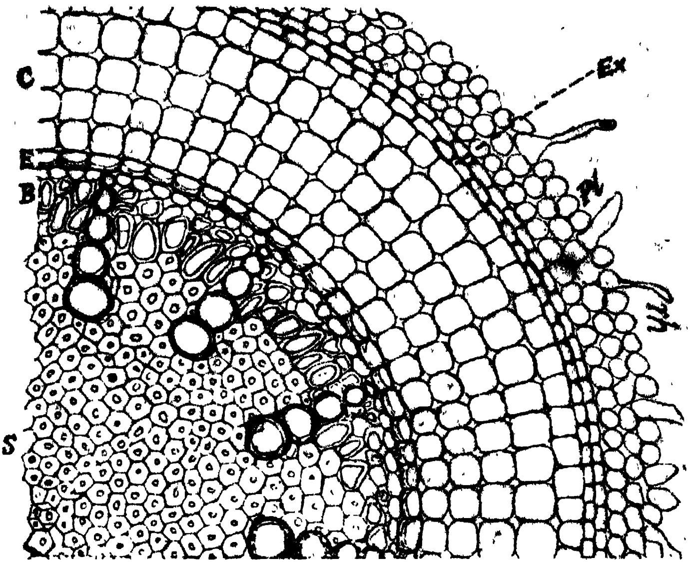


Fig. 305. Cross-section of a Grass-root (one-fourth)—only four xylem and with them alternating four phloem bundles (B) are shown.—Ex, exodermis; Pl, piliferous layer; rh, root hairs; C, cortex; E, endodermis; S, the medulla.

immediately surrounds the stele, is a very prominent feature of the root; it is called the **endodermis**. It forms a single layer of close-packed cells which shut off the conducting tissues of the stele from the air-containing cortex. It is used for the storage of food and acts as a nutritive layer in the formation of lateral roots. In the older part of the root the outer cortical layers are more and more exfoliated in consequence of growth in thickness of the root, and then the cells of the endoderm divide to form the bark or a corky covering for

the root. The endodermis forms the inner limit of the cortex. It is often distinguished as a starch-containing sheath around the stele.

The stele consists of a zone of pericycle on the outside and the bundles; the pith is often absent. The reason is that the stele of the root is developed *centripetally*, towards the centre or the axis, and not *centrifugally* or away from the axis as in the stem. The stem must be rigid and must be capable of resisting bending stress, and hence the harder tissue must be placed near the circumference, as far away from the centre as possible, leaving a soft parenchyma or pith in the centre. The root, on the contrary, must bend continually this way and that and seek sources of moisture in the soil; it must be flexible, and so the harder tissues (xylem) of the stele are formed towards the centre. This arrangement gives the necessary degree of flexibility to the root. The pericycle encircling the bundles forms a thin layer of parenchyma, often a single layer of cells, which is chiefly concerned with the production of lateral roots (fig. 304).

The bundles of the root are arranged in a ring as in a Dicot stem, but they are very different from those of the stem. The xylem and phloem lie not one behind the other, on the same radial line as in the stem, but sidewise on two different radi of the root. Hence they are called radial bundles (as opposed to the collateral bundles of the stem), the xylem and phloem forming separate strands radially disposed and alternating with each other (figs, 304, 305). The xylem portions form separate radial plates alternating with an equal number of isolated strips of phloem. The number of xylem "rays" (or *archs*) is typically two, three, four, rarely more: they often meet in the centre leaving no pith (fig. 306). Each xylem ray begins differentiation from below the pericycle and advances towards the

centre, so that the protoxylem elements (fig. 306) lie near the pericycle and the metaxylem lies innermost towards the axis. The primary bundle of the root thus develops *centri-petally*, *i.e.*, from the outside towards the centre. This is just the opposite of what occurs in the stem where the

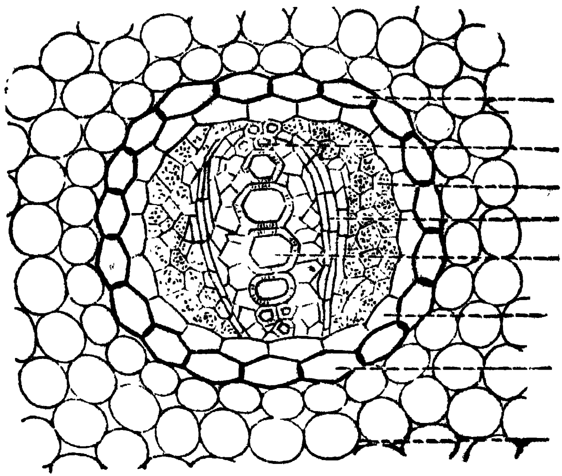


Fig. 306. Cross-section of a young Dicot root—diarch or two-rayed. E, endodermis ; Pr.X, protoxylem ; Ph, phloem ; Ca, cambium ; X, xylem ; Pe, pericycle ; Co, cortex.

bundle develops *centri-fugally* (see p. 232). The xylem and phloem consist chiefly of vessels and conducting parenchyma. Mechanical cells such as bast fibres, wood fibres, and sclerenchyma are not formed in the root.

The **Monocot root** differs from the above mainly in the presence of (1) a larger pith, and (2) a much larger number of bundles. The xylem rays of a Monocot root do not meet in the centre. It should be noted that the bundles are scattered in the Monocot stem, but in the root they are arranged in a ring as in Dicots ; further there is no

endodermis in the Monocot stem, while it is always present in all roots—Monocot or Dicot, and very prominently in Monocots.

Monocot roots do not generally grow in thickness like Dicot roots, and hence the endodermis is never ruptured. It is present as a very firm layer even in old roots, and then its radial and inner walls are very strongly thickened (see fig. 305). The cortex also is not exfoliated as in Dicot roots but in older parts which have shed their root-hairs

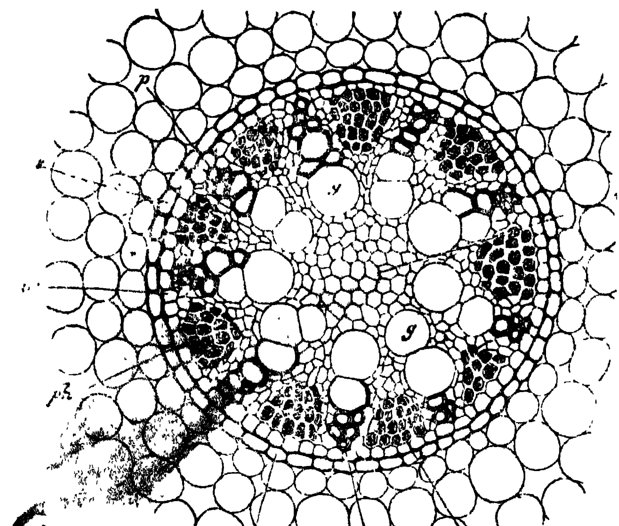


Fig. 307. Cross-section of a Monocot root (polyarch or many-rayed)—showing the radial bundles, the thick-walled endodermis s, and the pith m; ph, the phloem; g, the metaxylem; p, the protoxylem; s, the endodermis; pc, pericycle.

the outermost layer of cortical cells become converted into a protective layer of thick-walled cells called the **exodermis** (fig. 305).

Origin of secondary roots.—Branches of the root take their origin from the pericycle of the parent root. The cells of the pericycle just opposite a xylem plate, or between the xylem and phloem strands, divide and form a small mass of meristem which gradually protrudes out (as shown in fig. 304) and grows and differentiates like the primary meristem of the root as described on p. 209. The small root must break its way through the whole thickness of the primary cortex of the parent root (fig. 304). Thus secondary roots have an *endogenous* origin. And as they first arise just in front of, or on the two sides of each xylem ray of the parent root, their number is either equal to or double the number of bundles present in the parent. Outside they form straight rows on the main root, equidistant from one another, or in pairs of rows, accordingly as they arise opposite to or on the two sides of the xylem plates. When well-developed the xylem and phloem portions of the main and the branch roots are joined together.

The **Dicot leaf** in cross-section shows the three primary tissues, epidermal, cortical and vascular, specially modified in a manner characteristic of the leaf. The epidermis forms, as in the stem, a continuous layer of close-packed cells, rectangular in cross-section (fig. 308), but it is specially characterised by certain pores or intercellular spaces (S) called **stomata**. The outer cell-wall is thickened to form a cuticle and hairs may be developed in addition. The stomata are developed more on the lower surface of the leaf while the upper surface which is exposed to the sun has a tendency to develop a thicker cuticle or cutinised hairs. The cortical region of the leaf consists wholly of parenchyma filled with chloroplasts and is hence a chlorenchyma. This is commonly called the **mesophyll**. It consists of two distinct parts, *viz.*, (1) the *palisade parenchyma* and (2) the *spongy parenchyma*. In the normal leaf which is *dorsi-ventral*, with its two surfaces

facing the sky and the earth respectively, the palisade tissue occupies the upper part directly below the upper epidermis,

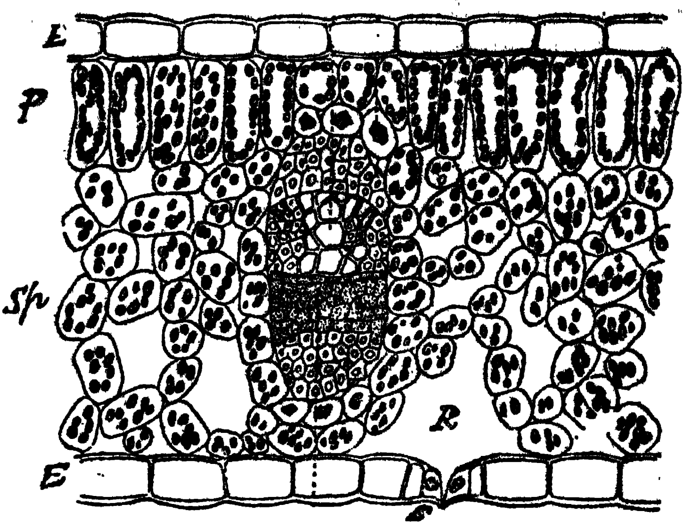


Fig. 308. Diagrammatic cross-section of a leaf, E, the epidermis with the cuticle on the outside. P, the palisade parenchyma. Sp, spongy parenchyma. The elliptical structure in the centre is a bundle surrounded by the bundle-sheath containing starch.

and the spongy parenchyma the lower portion of the mesophyll. The palisade parenchyma consists of rectangular cells elongated at right angles to the surface, and packed closely in rows so as to leave little intercellular spaces (*P*). The spongy mesophyll (*Sp.*) consists of cells irregular in outline and very loosely connected, so that large intercellular spaces are left. Larger cavities called *respiratory cavities* (*R*), occur below the stomata. The palisade tissue is the assimilating tissue of the plant; the spongy tissue constitutes the ventilating system of the leaf, the intercellular spaces of the leaf communicating with the air through the respiratory cavities and stomata.

The differentiation of the mesophyll into an upper palisade and a ower spongy tissue is due to the difference in exposure to light. The

upper surface receives direct light which penetrates the leaf to a certain extent and becomes also more heated than the lower part. Consequently the cells of the upper half of the mesophyll are so formed that they absorb all the available amount of sunlight penetrating the leaf by being as compact as possible. The chloroplasts place themselves in line with the light rays (see fig. 308 p). The lower portion of the mesophyll receives only the light which is not absorbed by the upper, and since this is almost negligible, the number of chloroplasts in the spongy cells is never large. This influence of light is best seen in sun-leaves' and shade-leaves. In many plants which live in open sunny places the palisade is very pronounced, occupying more than half the mesophyll; either the cells are very long, or the palisade tissue itself is made up of two or more tiers. The spongy tissue is correspondingly less developed. On the contrary in shade plants the palisade is not very conspicuous, neither are the cells so long, and the spongy tissue makes up the major portion of the mesophyll. It is for this that the foliage of shade plants is far more tender and soft than that of plants which live in the open. Sun-leaves are thicker, for they practically absorb all the light that fall on them: they have a thick palisade. Shade-leaves are thinner and greatly expanded, for they have only diffuse light to absorb and for this a greater surface must be exposed.

The vascular bundles of leaves are repeatedly divided, for every part must have water carried to it. The repeated division and reticulate arrangement of the veins also serve to support the greatly expanded tender parenchyma of the leaf. Each bundle has its xylem turned towards the upper surface, pouring its water to the heat and light-absorbing and assimilating cells of the palisade, and the phloem near the spongy parenchyma. The mechanical cells are mostly absent. The xylem consists mainly of spiral vessels and tracheides; the phloem of sieve-tubes and companion cells. The nerve-ends or the small veinlets are still further reduced, there being only a few spiral vessels surrounded by a conducting parenchyma, and no trace of the phloem elements. The larger bundles are surrounded by a sheath of parenchyma, called the *conducting sheath,* which conducts the carbohydrates, the xylem carrying water and the phloem only the albuminous matters.

The structure of a Monocot leaf agrees in the main with that of a Dicot. In fact all dorsi-ventral leaves, *i.e.*, those presenting their two faces to the earth and the sky respectively, have (1) an upper and a lower epidermis with an

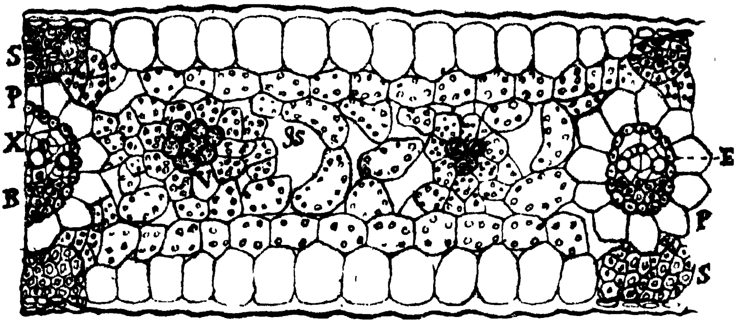


Fig. 309. Cross-section of a vertical Grass-leaf.

external cuticle and stomata mostly on the lower side, (2) a mesophyll differentiated into the upper palisade parenchyma and the lower spongy parenchyma, and (3) the vascular bundles traversing the mesophyll. In the leaf of a Monocot, however, the bundles are characterised by a thick sclerenchyma sheath, (fig. 309E), as in those of the stem. Sometimes the fibrous tissue (sclerenchyma) surrounding the xylem and phloem extends to the upper and lower epidermis and the bundles thus act as struts or girders supporting the soft tissue of the mesophyll. In many cases strings of sclerenchyma (S) run just below the epidermis, often parallel to the bundles, and give the necessary mechanical rigidity. In such leaves, as those of Grasses, Lilies and other Monocots, which are not dorsi-ventral but more or less vertical, the mesophyll is not differentiated into an upper palisade and a lower spongy tissue, as in ordinary leaves. In these vertical leaves the epidermis on both sides shows similar structure, both bearing stomata, and the mesophyll has a middle spongy tissue bounded on both sides by a

palisade, as shown in fig. 309. Such leaves are hence said to be *isolateral*. The veins of a Monocot leaf run in parallel line; they can not support the ample parenchyma of the large lamina and so the sclerenchyma strings are developed just below the epidermis to give support. Each bundle contains an upper xylem and a lower phloem, is surrounded by the sclerenchyma, and the whole enveloped in a parenchymatous bundle-sheath (fig. 309P) which conducts the carbohydrate matters.

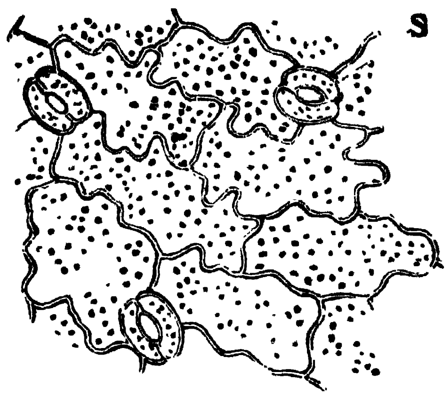


Fig. 310. Surface view of the epidermis of a leaf showing stomata S.

The **epidermis**, as has been seen, is a continuous layer of cells covering all young organs. It is differently formed at different parts. The root-epidermis or the epiblem is an absorbing tissue; it produces root-hairs and is soon lost and replaced by the exodermis. The epidermis of the stem and leaf is a protective layer producing the cuticle and hairs on the outside and also possesses the ventilating pores called stomata.

The **stomata** (*sing.* stoma) are holes or openings in the epidermis. They are special intercellular spaces between certain cells of the epidermis, called *guard cells*, which regulate the opening. Below the opening occurs an empty

air space, called *respiratory cavity* (p. 236). The guard-cells are elliptical or somewhat cylindrical cells, bent in such fashion that they join broadly at the ends but are free at the middle as shown in fig. 310S. In surface view each stoma looks like the human eye. The walls of the guard-cells are thickened, except that which joins each to the epidermal cells (fig. 308) so that they can move as if on a hinge. Guard-cells are always living cells full of chloroplasts and starch grains, and in this they differ from the epidermal cells generally, for the latter are often dead and empty.

The function of a stoma is to permit the entrance and exit of air into the plant; it also serves as the passage through which the plant gives away to the air the excess of water which it contains in the form of aqueous vapour. But this egress and ingress of gases must neither be too rapid nor too slow. *i.e.*, must be controlled according to the requirements of the plant. The function of the guard-cells is to regulate the opening or the diameter of the stoma. They move so as to narrow or widen the stoma, and this movement is regulated by light, humidity, and air-currents. As a rule stomata open in strong light and close in weak light. The guard-cells are very sensitive to different intensities of light, and they open just as much as is necessary for the plant under a certain degree of illumination. During the day the stomata are open more or less; at night they are closed, the guard-cells falling like eyelids.

Stomata occur in all green parts of plants, but they are most abundant in leaves. In ordinary leaves which spread flat or horizontally (dorsi-ventral leaves), they are more abundant in the lower epidermis, while in vertical leaves, such as those of many Grasses, they occur equally distributed on both surfaces. In firm, horizontal, shiny leaves, such as those of Banyans, Mango, etc. they occur only on the lower surface while the upper surface has a very thick cuticle with or without a waxy coat or bloom. They are absent from submerged or underground (scale) leaves In floating leaves, such as those of Water-lily, Lotus, etc, they occur on the upper surface alone.

CHAPTER XVIII.

SECONDARY TISSUES.

Growth in thickness of Dicot stem.—Soon after the completion of the primary tissues of a Dicot stem, new tissues called secondary tissues make their appearance. They are formed by secondary meristems which develop in the parenchyma as a result of the continued activity of the cambium. The cambium belonging to the bundle is the primary cambium; it is called the *fascicular cambium* (from *fascicle* = a bundle). Its cells divide rapidly and the new cells cut off continuously towards the xylem and phloem sides become eventually transformed into newer elements of the xylem and phloem respectively. Thus the mass of the vascular wedge is gradually increased. A new cambium soon arises in the medullary rays. The strips of the primary medullary rays lying between the cambium tissues of successive bundles begin to divide their cells and thus assume a meristematic character. Thus arises the secondary meristem in the stele forming short strips called *Inter-fascicular cambium* layers which join the cambium of the bundles and so form a complete *cambium ring* (fig. 311 B). The latter is thus composed of two distinct meristems—the fascicular cambium is the primary, while the inter-fascicular cambium is secondary in origin. This cambium ring cuts off cells both inside and outside; those cut off inside towards the xylem go to form the secondary xylem or wood, while those produced on the outside become developed as secondary phloem or bast.

The fascicular cambium produces: (1) secondary xylem tissues on the inside, (2) secondary phloem tissues on the

outside, while (3) at certain points living parenchyma cells are cut off which are not either xylem or phloem but form radial plates of parenchyma. In fig. 311 C such plates are

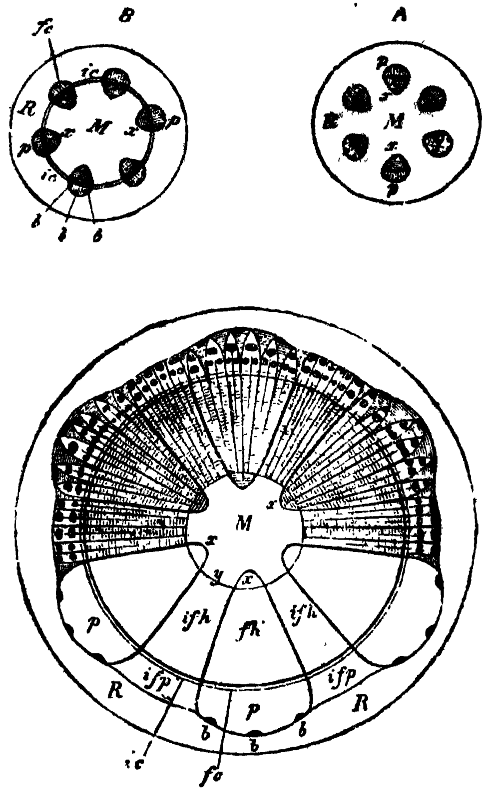


Fig 311. Diagrams showing secondary growth in thickness.

A.—the primary stem with the primary tissues; R, cortex; M, medulla; x, xylem and p, phloem B.—primary stem (older) beginning to form secondary tissues; fc, fascicular and ic, inter-fascicular cambium joining to form the continuous cambium ring. C.—The upper half shows the secondary tissues formed from the cambium-ring; x, x, the proto-xylem elements forming the medullary sheath (y); fh, secondary wood; p, secondary bast; b,b,b, primary phloem; ifh, ifp, are wood and bast formed by the cambium ring.

shown as dark lines or rays traversing the bundles now augmented by the secondary xylem and phloem. These rays are termed the **secondary medullary rays.** They serve to supply the inner tissues of the bundle with plastic matters formed in the cortex, and also to carry water to the outer cortex from the xylem, thus placing all the tissues in communication.

The **Inter-fascicular** cambium at first prepares new secondary bundles in the primary medullary rays running between the primary bundles. In a short time many such secondary bundles are formed and soon the whole system of vascular tissues becomes a compact ring and then there is no difference in the action of the fascicular and inter-fascicular cambiums. In a grown up Dicot stem this vascular ring appears split up into numerous thin wedges, as shown in fig. 311 C, separated from one another by thin strips of the secondary medullary rays. The first formed primary bundles at this stage and afterwards are driven into the central pith by this growing ring of wood and then appear to form a sheath round it, termed the *Medullary Sheath.*

Elements of secondary growth.—The tissues which comprise the secondary xylem or wood of Dicots are :—(1) wide tracheides with bordered pits, (2) wide vessels or tracheæ which are usually of the reticulate or pitted type, (3) wood-fibres or elongated fibrous tracheides, and (4) wood parenchyma. On the whole these elements are bigger than those produced in the primary bundle. Those which constitute the secondary phloem or bast are :—(1) sieve-tubes with companion cells, and (2) bast fibres or elongated sclerenchyma cells, and (3) bast parenchyma or small thin-walled living cells. The sclerenchymatous bast fibres form what is commonly known as the *hard bast*, as distinguished from the sieve-tubes and companion cells which form the

soft bast. Besides these secondary tissues the cambium ring also produces the radial plates of parenchyma—the secondary medullary rays.

In Pines secondary growth takes place exactly as in Dicots but the whole mass of secondary wood consists of vasiform and fibrous tracheides with bordered or scalariform pits. True vessels or tracheæ are not developed. The secondary medullary rays consist not of small-celled parenchyma as in Dicots but mainly of radially placed tracheides. The secondary phloem has no companion cells but only sieve-tubes and bast parenchyma.

Annual rings.—The activity of the cambium ring depends upon the season of the year. In spring, the period of active vegetation, the roots absorb a large quantity of water from the soil and the leaves evaporate a corresponding quantity. Consequently the secondary wood produced by the cambium in spring consists of very wide vessels or tracheæ. These wide xylem tissues are better adapted for a rapid and long-distanced transport of water. They form the *Spring-Wood.* Late in the winter of the same year the cambium is less active, is sometimes entirely dormant. This is the period of least vegetative activity. Leaves fall and buds remain dormant. Nor is there much water in the soil, and the roots are not so actively absorbing water. The elements which are added to the wood by the cambium at this period are not wide because they are not much required to conduct a large volume of water : they are hence fibrous tracheides and dense close-packed parenchyma, or at most bordered-pitted tracheides. All these tissues are dense and stand out in sharp contrast to the looser wider elements of the spring wood, and form what is called the *late* or *autumn wood.* Thus in each year there is produced two layers of xylem tissues, one formed during autumn or winter consisting of denser smaller elements, and the other formed during the spring con-

sisting of wider and bigger elements. In a stem several years old these layers regularly alternate and form concentric rings called **annual rings.**

In a very thick stem or the trunk of a tree the inner older part of the wood generally dies and ceases functioning as the water conducting tissue; it becomes harder and firmer than the outer part, and usually becomes distinctly coloured by various matters, such as tannins, gums. It is then called the **duramen** or **heart-wood** in contrast to the **alburnum** or the **sap-wood**—the still active, soft, and light-coloured later annual additions. The inner layers of the alburnum gradually transform into those of the duramen as years pass on. The cells of the duramen are protected by resinous matters with which they are filled. It is the presence of these coloured and resinous substances that imparts to the wood its 'timber value.' In some Dicot plants, however, the duramen though dead is not coloured or filled with any gummy matter. Such wood is very soft and prone to decay, and has really no timber value (*e.g.* Sajina), while again in others there is no formation of the duramen, the whole wood being living. This is known as the *splint-wood*.

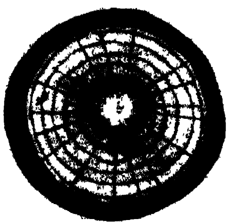


Fig. 312. Cross-section of a thick Mango stem showing annual rings × 10.

Secondary growth in roots.—Roots of Dicots and Pines usually grow in thickness like their stems. The bundles of the root are radial and have at first no cambium. Gradually the part of the stelar parenchyma lying inside the phloem strands become meristematic by constantly dividing their cells, and eventually form a continuous layer of cambium. This, as shown in fig, 313 C, is at first sinuous, the separate cambium layers originating inside the phloem being united

behind the xylem strands. This cambium tissue differs from that of the stem in being entirely secondary; here is no distinction between the fascicular and the inter-fascicular portions. But like the cambium-ring of the stem the sinuous cambium layer of the root produces secondary bundles just in front of the primary phloem as shown in fig. 314. The secondary phloem or the bast (B) lies in contact with the primary (P), but the secondary xylem (W) has no connection with the primary xylem (X). Gradually as growth goes on the cambium looses its sinuous contour and becomes straightened out into a ring. Greater activity in the cambium gives rise to a complete ring of wood exactly like that in the stem, and the primary xylem strands are more

Fig. 313.

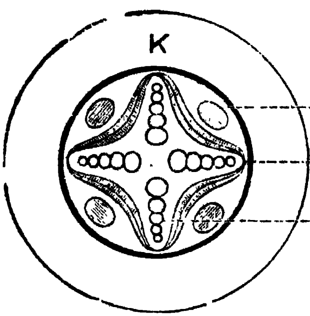


Fig. 314.

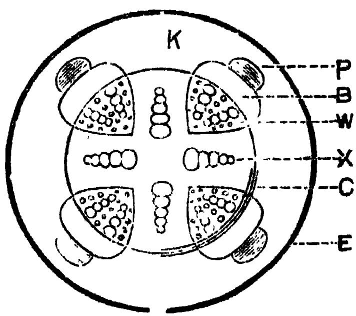


Fig. 313. Young Dicot root showing secondary growth. K, the cortex; P, a phloem bundle; C, the sinuous cambium formed in front of the four phloem bundles; X, the primary xylem bundles (four).

Fig. 314. Old Dicot root. K, the secondary cortex; P, the primary phloem; B, the secondary phloem; W, the secondary xylem formed from the cambium C; X, the primary xylem.

and more pushed towards the centre, if they have not already met there as shown in fig. 314. The further growth of this cambium and its products takes place exactly as in the stem, so that a cross-section of an old root in which secondary growth has continued for some years can hardly be distinguished from that of a stem. But in the stem

there is always a pith, the bundles being developed centrifugally, while in a root the primary xylem tissues are in the centre in the form of separate *rays* or plates. Further the wood of the root is softer and more uniform than that in the stem. For, climatic variations which give rise to the annual rings of the stem do not much affect the root, and hence annual rings or a hard duramen is hardly present. It is for this that the wood of the root is useless as timber. It is soft and easily rots away.

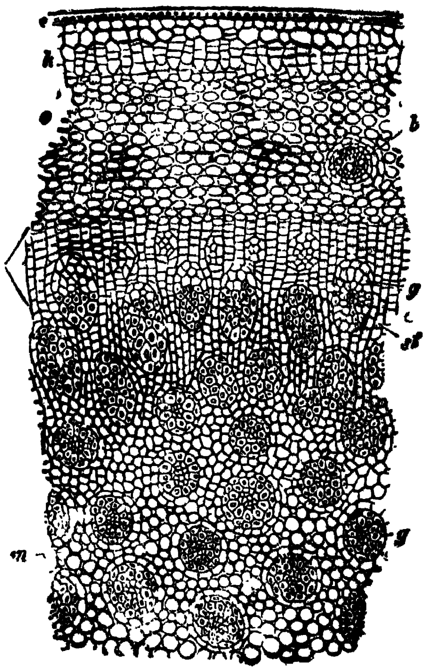


Fig. 315. Part of a cross-section of the stem of Dracaena, e, epidermis; k, phellogen; r, cortex; b, a leaf-trace; x, the cambium ring forming secondary bundles g; m, ground tissue of the stele.

The cortex of the root is gradually exfoliated as the root grows in thickness (fig. 314). The endodermis is gradually

stretched more and more, and it soon produces a cork-cambium (p. 249) which by active division of its cells forms a protective layer of cork or bark on the outside and a secondary parenchymatous cortex on the inside (see below).

In Monocots there is no secondary thickening because there is no cambium (p. 227). In Palms the primary meristem is considerably enlarged and hence the columnar form of the stem. The thickness of Palm stems is due entirely to the continued expansion of parenchyma cells already existing in the wide stele.

Secondary thickening is known in only a few Monocots, such as *Dracaena* (Khun-kharapi), *Yucca*, and Aloe. The ground tissue immediately surrounding the stele begins to divide its cells, and so a new cambium is formed. In this are formed separate closed bundles, as shown in fig. 315.

SECONDARY DERMAL OR SKIN-TISSUES.

Cork and Bark—When the stem begins to increase in thickness the epidermis no longer affords sufficient protection. For, in the first place, the epidermis is after all a delicate layer and is not consequently well-fitted for the protection of bulky organs, and secondly, as it is not much capable of subsequent growth it becomes soon ruptured and torn by the increasing growth in thickness of the stem. Hence when old the epidermis is replaced by a stronger dermal tissue or skin called the **periderm** or the cork-tissue. On the stem and the root it is formed soon after the secondary growth in thickness has reached a certain stage. The commencement of its formation is indicated by small brown patches on the surface of the stem which gradually loses its green colour, becomes pale and finally is covered by a brown layer.

The periderm is derived from a secondary meristem, arising below the epidermis, called the **phellogen** or cork-

Cambium, This consists of a layer of thin-walled, small (fig. 316) actively dividing cells with abundant protoplasmic contents. The cells by division produce radial rows of cells of which the outermost cells are more and more suberised and converted into dead impervious cork-cells. The cells cut off on the inside, towards the cortex, however retain their protoplasm, become enlarged, and so constitute

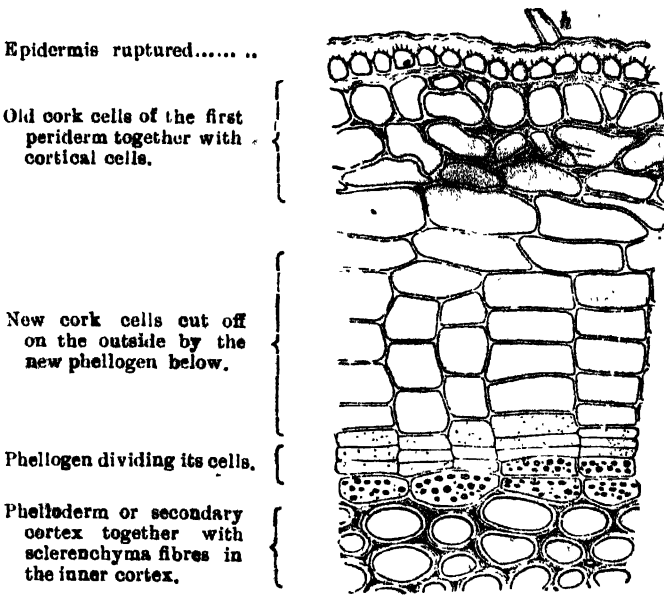


Fig. 316. Formation of Cork, Periderm and Bark.

a secondary cortex called phelloderm. The phellogen sooner or later ceases to divide, and itself becomes converted into cork. The periderm is the name given to the tissues which originate from the phellogen. It includes cork on the outside and the living secondary cortex or phelloderm on the inside.

The cells comprising the cork tissue are always dead and generally contain only air. They have a square or tabular shape and fit closely together without intercellular spaces. The walls are thoroughly suberised and may be extremely thick. This makes the layer impervious to water, so that loss of water is prevented and the inner cortical tissue is well-protected from injuries, especially from the attack of fungal parasites. The cavities of older, thicker cork-cells are filled with yellow or brown substances (tannins and other waste matters).*

In many woody plants the phellogen arises at a greater depth from the surface, in a deep-seated layer of the cortex. The cork-cells formed on the outside of this phellogen being impervious to water, they cut off all the other outer tissues from water-supply. These outer cortical cells consequently soon die and dry up, and together with the cork-tissue constitute the thick structure known commonly as the bark.

Bark is a very complex dermal tissue. A typical bark comprises, in addition to corky layers, a variety of tissues which originally belonged to the cortex, phelloderm, or even the bast of the phloem. The first formed phellogen generally ceases its activity after a short time *i.e.* it is soon closed. A second deeper lying phellogen is however soon formed to keep pace with the increasing growth in thickness which may rupture the first formed periderm. After a time this new phellogen also closes and between the two periderm layers is enclosed a strip of the living cortex which, however, soon dies owing to want of water and food supply. Deeper still a third phellogen arises some time after, and in this way a phellogen may spring even in the outer parenchyma of the phloem. All tissues lying outside the innermost layer of cork produced by the innermost layer of the phellogen eventually die and constitute the bark. The outer dead cells become filled with various decomposition products and

such waste matters as tannins, alkaloids, etc. These however preserve the bark from the action of destructive agencies.

The bark of a plant comes off in thick or thin scales or rings. Sometimes it can be peeled off like a sheet of paper, as in the Bhurja-patra tree (*Melaleuca leucadendron*).

Lenticels.—As the epidermis is gradually replaced by the periderm so the stomata are replaced by *lenticels* or *cortical pores*. They are holes in the periderm. They serve to maintain the gaseous interchange between the outside air and the gases present in the intercellular spaces of the plant. They form yellow or brown specks on branches going to form the periderm. Each lenticel takes its origin from a special phellogen layer formed directly under a stoma (fig. 317). This phellogen does not cut off cork cells but certain loose

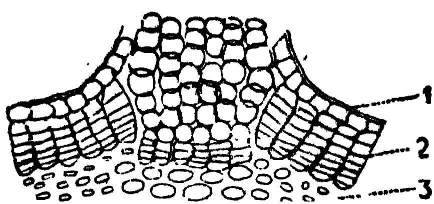


Fig. 317. Formation of Lenticel. 1. the ruptured epidermis; 2. the phellogen giving rise to the loose cells that pack up the opening; 3. cortical cells.

roundish cells, called complementary cells, which are distinguished in having intercellular spaces between them. The complementary cells press the epidermis outwards, finally rupture it, and then slightly budge out. But the loose cells of the complementary tissue are prevented from falling to pieces by firmly united layers of cells, called *closing layer*, which the phellogen produces in addition from time to time. This lenticel-forming phellogen is connected laterally to the ordinary phellogen of the periderm.

Fall of leaves:—Leaves are periodically shed specially in those regions where a long hot and dry period follows the short rainy season, and also where the winter is very cold and stops vegetative activity. In such places old leaves are shed annually and new ones are formed in the spring. But in districts where the climatic changes are not severe old leaves simply dry up and decay, the plants being never bereft of leaves at any time. Such plants are said to be *evergreens*. Herbaceous plants do not shed their leaves. The phenomenon of 'leaf-falls' is characteristic of certain deciduous woody trees alone (Shajina, Banyans, Silk-cotton trees etc.) When the north wind begins to blow and winter approaches the leaves begin to change colour, shiver in the cold air and then fall. The separation is brought about by the formation of a tissue, termed the *layer of separation* or the **abscise layer**, at the base of the petiole shortly before the leaf-fall. This tissue consists of a parenchyma the walls of which easily separate by the conversion of the primary layer into a mucilaginous matter. As it attains maturity the tracheal elements are narrowed, the parenchymatous ground tissue surrounding the vascular tissues becomes all changed into the cells of the separation layer, and then the most trifling cause will split up its loosely held cells. The absciss layer cuts off the parenchyma of the petiole from its base and then the slightest wind can break the shrivelled xylem by which the leaf hangs.

THE COURSE OF VASCULAR BUNDLES.

Bundles that pertain strictly to the stem being differentiated in the terminal bud, and grow along with it, are called **cauline** bundles. And bundles that originate at the nodes and grow out horizontally or obliquely to the leaves and vertically down into the stem are called **leaf-trace** bundles or **common** *bundles*, because they are common to the stem

and the leaf. The bundle-system of the stele of higher plants is generally composed of leaf traces alone. Cauline bundles are found in Fern-like plants.

In Dicots generally all the primary bundles are common bundles. From each node they bulge outwards to the leaf-rudiment and inwards towards the centre of the stem. They then pursue a direction downwards parallel to the sides of the stem, pass down through more than one inter-node, and are arranged equidistant from the centre ; in cross-section the characteristic *ring-like* arrangement is thus observed. The bundles that proceed from the leaves at a particular node insert themselves to those that run from the lower ones, and in this way the form of the ring is maintained. In a few Dicots the bundles follow a different course. Thus, in the Cucumber family the bundles though all common are arranged in *two rings* (fig. 319) ; some form the ordinary typical ring, while a few others bend more towards the centre and form a second irregular ring.

In Monocots too the bundles are common ; in the stem they are never in a ring (as in Dicots) but scattered. In Grasses the bundles occupy only the peripheral part of the the ground tissue and the central part becomes hollow. In Palms, on the other hand, the bundles are scattered over the whole fundamental tissue even in the centre (see fig. 302). The bundles of Palms are common. From the insertion of each leaf a number of bundles pass down the stem bending considerably inwards towards the centre, descend through several internodes, and finally curve out towards the periphery, there to unite with other leaf-traces. Thus in a transverse section of a palm-stem, the outer part of the ground tissue is crowded with bundles which become fewer in number towards the centre.

In roots the xylem and the phloem form separate strands (see radial bundles p. 232). A bundle passing through the

stem to the root becomes not only split up into its two parts xylem and phloem, as soon as it enters into the region of the root, but each xylem strand becomes at the same time twisted through an angle of 180°, so that what was the inner side of the xylem in the stem becomes now the outer. Hence in roots the protoxylem is nearer the cortex and the metaxylem faces the centre.

The xylem and phloem tissues of a bundle are differently arranged in different cases. Accordingly there are various **kinds of vascular bundles.**—

1. **Collateral** bundles are those which have xylem and phloem side by side, the xylem facing the centre of the stem towards the apex and the phloem on the outer side of the xylem. This is the most common type and characterises the shoots of Dicots and Monocots generally. A collateral bundle

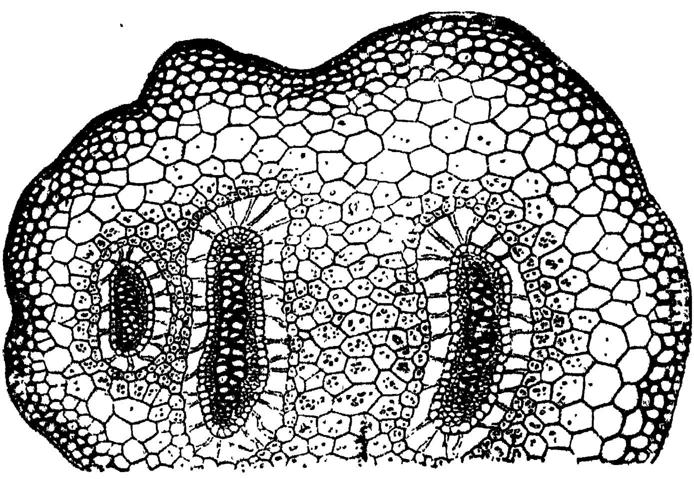


Fig. 318. Cross-section of the stem of *Selaginella*—showing three concentric bundles in the ground tissue. In each bundle the centre is xylem (the dark cells) surrounded by the phloem.

is said to be (a) *open*, when, as in Dicots, there is a layer of cambium separating the xylem from the phloem, and (b) *closed*, when, as in Monocots, there is no cambium.

2. **Bicollateral** bundles are those having two strands of phloem on the two sides of a central xylem, the three lying on the same radial line. They occur in a few Dicots only such as the Cucumber (fig. 319) and other plants belonging to its family.

3. **Radial** bundles characterise all roots. They consist of xylem and phloem in separate alternating strands, the

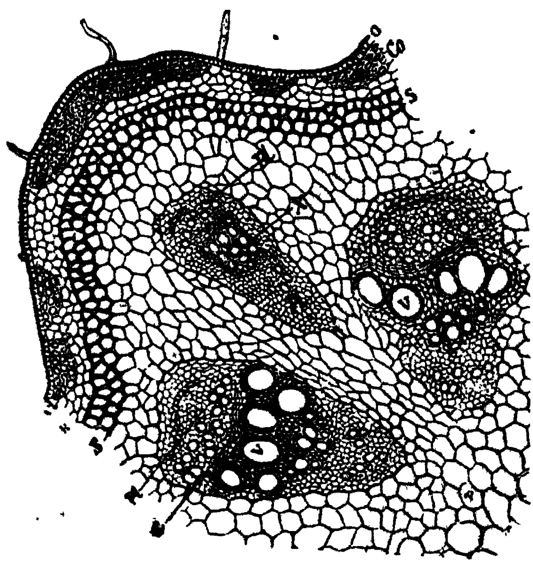


Fig. 319. Part of cross-section of Cucumber stem showing three bicollateral bundles. Co, patches of collenchyma in the outer cortex K; S, S, ring of sclerenchyma; X, xylem; Pl, phloem; V, tracheæ C, cambium.

proto-xylem being towards the outside, not facing the axis or centre of the stem as in the last two cases.

4. Concentric bundles or those having a central phloem surrounded by a ring of xylem, or a central xylem surrounded by phloem, occur rarely in the higer plants but are found in the Ferns. The so called bundles, really steles, of Fern-like plants (fig. 310) have thick plates of xylem in the centre surrounded by phloem.

QUESTIONS.

1. Describe the internal structure of a young Dicot stem. Compare it generally with that of a Monocot.

2. Describe the anatomy of foliage leaves.

3. What are fibro-vascular bundles and why are they so called? Describe the tissue-elements of the various bundles found in plants.

4. Give an account of the secondary skin tissues of a plant.

5. Describe the internal structure of roots. Where and how does the root grow in thickness?

6. Explain how plants grow in thickness. What are annual rings? Distinguish between HEART-WOOD, SAP-WOOD and SPLINT-WOOD.

7. Write what you know about stomata. What are lenticels and how are they formed?

8. Why and how do leaves fall?

9. Describe the course of vascular bundles in the plant.

10. What and where are the following?—hypoderma, alburnum, epiblem, medulla, exodermis, phelloderm, phlœoterma, leaf-trace, bast, guard-cells, absciss layer and periderm.

PART III

PHYSIOLOGY OF PLANTS

CHAPTER XIX

VITAL FUNCTIONS

Physiology enquires about plant-functions. These are mainly (1) *Nutrition* and *Growth*, (2) *Response* and (3) *Reproduction*. A plant grows by absorbing and assimilating food and then after a certain period reproduces itself. But these functions are to a great extent influenced by external factors, such as light and air, moistness of the atmosphere, nature of the soil and so on. Consequently the *influence of external factors on plants*, and their behaviour in response to such factors, constitute important problems of physiology.

Germination can not take place unless seeds be moistened with water, and in the act a large amount of water is taken up by the swollen seedlings. Next, the development of the seedling can take place only when it is supplied with food-matters and of these water is the most important. It is absorbed from the soil by the root-hairs, not in a pure state but in the state of a very dilute solution, having dissolved in it various inorganic matters of the soil. The water which saturates the soil always contains a certain percentage of the solid constituents of the soil dissolved in it, for, of all liquids water is the greatest solvent known. The cell-wall of the root-hairs consists simply of cellulose, and it is easily permeable to water. The water of the soil thus easily goes into the plant. For plants, like animals, drink and breathe, but they can not eat solid food for obvious reasons. Like animals also they require raw materials for their nutrition and these are secured from the soil in the form of minerals. These minerals pass into solution, though only partly, and those that are insoluble in pure water are

dissolved by an acid which the active root-hairs secrete. Thus, in point of nutrition, there is this great difference between plants and animals that whereas the former depend entirely upon the inorganic matters of the earth, animals live only on plants or on plant-eating animals; they are, in a sense, parasites on the vegetable kingdom.

That a part of solid earth is used up by plants is evident from the fact that agricultural lands become gradually impoverished by long cultivation. It is for this that manures are used. It is not difficult to convince oneself that plants take in minerals from the soil. A grown-up seedling weighs much more than its seed; this may be explained by the fact that it absorbs a large quantity of water. This is precisely so, but if we burn the seed and the seedling separately and then compare the weights of the ash left by them we find that the ash of the seedling is much greater. Further, the incomparably large volume and weight of solid wood in a tree which comes out from a tiny seed, as well as the mass of ash which this wood leaves behind when burnt, are convincing proofs that a part of the constituents of the soil enters into the structure of a plant.

The first nutritive function of a plant then is absorption of raw food from the soil. This is done by the root-hairs. The next is the conduction of the raw materials to the leaves where they are assimilated. The conduction takes place through the xylem tissues of a plant, whereas the chlorenchyma is the sole assimilating organ of green plants. By assimilation starch, sugars, proteids, and other carbohydrates and nitrogenous substances, including protoplasm, are prepared. These *plastic products*, as they are called, are then sent to the growing parts of plants where the protoplasm handles them in such a manner that growth or the formation of new structures takes place. It often happens, however, that they cannot be put to any immediate use or

that there is a large surplus, and then they are conducted to certain places, termed reservoirs of assimilated matters, to be stored temporarily for future use. Thus, in the plant-body, there is a constant migration of matter—of raw food travelling to the assimilatory organs (chlorenchyma of leaves and stems), of assimilated food travelling by the phloem and the bundle-sheath to the growing points of plants, or to the reservoirs of food matters.

Without air there can be no life, no assimilation. Like animals plants also must breathe or respire. In the act, oxygen is taken in from the atmosphere, the gas passes through the stomata and intercellular spaces, a part of the protoplasm or of the substances prepared by it is slowly oxidised, and carbon dioxide gas is formed. In the case of animals, the air is taken into the lungs, the oxygen oxidises a part of the blood or matters contained in it, and carbon dioxide gas is formed which is given out. Respiration is really a process of oxidation whereby heat or energy is given. The burning of fuel is a case of very rapid oxidation and of evolution of intense heat. When plants and animals breathe, the oxygen of the air they take in slowly burns up a part of their protoplasm and such things, and the heat set free gives energy to the whole system. This heat maintains the body-heat of both plants and animals alike. Deprived of air plants and animals die, for, with the stoppage of respiration, the activity of assimilation also stops for want of the necessary energy or driving power, and with it the constructive process leading to growth.

Like air light is also indispensable to plants. Light acts not only as a stimulus to growth but also more directly on the chlorophyll-apparatus of plants. Plants turn pale and yellow when deprived of light, and if kept long in this state, finally die. For, light stimulates the protoplasm to produce chlorophyll and chlorophyll is absolutely necessary for assimilation.

It will appear that all the above conditions must be fulfilled before there can be growth. Given air and light and raw food-matters there is assimilation; given assimilation and respiration there is growth. But growth implies also a certain *movement* of the parts growing. The growing shoot pushes its way up into the air, the growing root into the soil; both seek regions which they can further exploit for food, for conditions necessary for nutrition. Movement, though very much restricted in plants, is a consequence of healthy growth; it is a response to the call of external nature which in various ways falls upon the plant and disturbs it. It is very evident in twining plants, in the coiling of tendrils, in the zig-zag course of the roots, in the bending of flower-stalks, in the opening and closing of flowers, and in the leaves and stems of many shade-plants. In a healthy growing cell the protoplasm itself is in a state of flux, constantly changing the relative position of its particles. New matter is constantly flowing into it, and old assimilated or waste matters are flowing out; things are continually coming in and going out (see circulation and rotation, p. 172). Plant organs also are constantly striving to secure for themselves the best position. If light be injurious to an organ it moves away from light; if light be indispensable, an organ moves towards it. If it be intense and unbearable, the organ moves so that the full glare of the sun is avoided. So too, with regard to other external factors. Plant-movements are really adaptations to the environment; a response, that is to say, to the conditions of external nature under which it must live. It is this power of response which gives the healthy *tone* to the plant. Life does not consist of mere eating, drinking and breathing; a certain responsiveness to the outer world is as much a part of life as the other functions. Without it life is irresponsive and without its *tone*, that is, inactive, dull, or in popular language, *lifeless*.

In the following tables are set forth side by side the more important physiological functions and the organs concerned.

FUNCTIONS	ORGANS
A. NUTRITION	
1 Absorption of water and minerals	Root-hairs.
2. Conduction of the nutrient sap ...	Xylem tissues.
3. Absorption and storage of air ...	Inter-cellular spaces, Aerenchyma.
4. Assimilation	Chlorenchyma.
5. Transport of assimilated matter ...	Phloem tissues.
6. Storage of surplus food ...	Parenchyma of stems, roots, fruits and seeds.
B. RESPIRATION	All living cells.
7. Storage of waste matter ...	Inter-cellular spaces, glands, hairs, gum-, resin-, and other passages.
C. GROWTH	All growing parts.
D. MOVEMENT OR RESPONSE ...	All growing and young organs and certain special motile organs.
E. REPRODUCTION	Primordial cells, flowers, etc.

ORGANS	FUNCTIONS
ROOT	1. Absorption of water and minerals. 2. Fixation of plant on soil. 3. Storage of surplus food matter.
STEM	1. Carrying and developing the leaves and exposing them favourably to sun and air. 2. Distribution or circulation of food-matters—raw and assimilated—throughout the plant. 3. Storage of surplus food matter.
LEAVES	1. Assimilation and respiration. 2. Letting out of surplus water brought from the root
FLOWER	Reproduction by securing the best means of sexual union.
FRUIT	Preservation and dispersion of the seed.
SEED	Protection of the embryo and affording it food till suitable time when it can grow up as an independent plant.

CHAPTER XX.

PROTECTION OF THE PLANT.

Protection of the plant from injuries which must be more or less received from the outside world is secured in various ways. For, between plants and animals there is going on a continuous struggle for existence. Many animals live exclusively on vegetable diet and principally on the soft living green foliage which is the most important vital organ of the plant. Herbivorous animals can not, of course, foresee like men that it is prudent to let the plant grow and eat its fruit or seed. They wage a war of extermination on plants by devouring stem, root and all. But plants also are protected by various means.

First, **poison.** The latex of latex-bearing plants, such as Akanda (*Calotropis gigantea*), Poppies, spurges, etc, is as a rule, poisonous. In some cases it often causes blisters, as in Papaw and Chitra (Chitrika—*Plumbago zeylanica*). Deadly poisons, called *alkaloids*, are also formed in many plants. For instance, in Datura occurs the alkaloid *daturine*, in Kuchila (Nirmali—the strychnine plant) occurs the alkaloid *strychnine*, in Aconite (Kat-bish—*Aconitum ferox*) *aconitine*, in Cinchona *quinine*, in tobacco plant *nicotine*, in Kantikary (*Solanum xanthocarpum*) *solanine*, in the Opium plant *morphein*, and so on. Certain small herbs like the Amrool-shak (*Oxalis*) and Shooshny-shak (*Marsilia*) are very bitter for they contain acids in their cell-sap. In the common Kachoo and Ol, and in many water-plants raphides and irritating liquids are present in large quantities in the cells. These often give an itching sensation to the mouth, and may even cause serious inflammation.

Secondly, **hairs.** In certain plants there is a dense outgrowth of hairs on the epidermis which form a tangled woolly or silky covering. They are avoided by grazing animals because of the sense of nausea and choking which they feel when such a hairy leaf is chewed and devoured. The long dry hairs stick to the tongue or form a ball at the throat and can not be easily got rid of and the animal feels great uneasiness.

Thirdly, **weapons of defence** such as thorns, spines, prickles, and bristles. These are all sharp pointed structures capable of giving a smart wound to attacking animals. Thorns are arrested branchlets which transform their terminal buds into a hard lignified structure, also their lateral buds in the case of branched thorns (see p. 40). Spines are modified leaves or leaf-segments. Both thorns and spines have vascular bundles in which of course the vessels are not developed but are replaced by fibrous hard tracheides. A prickle, however, is a structure which proceeds from the sub-epidermal parenchyma (cortex) of an organ carrying over it the epidermis as well. It ends in a sharp pointed cell, but has no vascular bundle though it is often lignified. **Bristles** differ from all the above in being strictly epidermal in origin. They are cells of the epidermis which grow out and terminate in a hard point. They are also specially adapted as weapons of defence. Thorns are the largest of them all, and are formed in no definite direction. But the rest are often so directed that they may stand against creeping or crawling animals, such as snails, slugs, and worms. Thus, the prickles of Rose (fig. 53) are formed on the petiole and the stem up which the creeping animals must come in order to reach the green leaves. The leaves of Lotus are armed on the under surface and on the petiole with prickles, for they are exposed to the attacks of small aquatic animals and slugs.

The most remarkable plants in this respect are the Opuntias (p. 66) and Cactii. These plants have peculiarly-shaped swollen succulent stems which being green carry on the function of leaves, and the foliage is entirely suppressed and modified into long spines. Bristles and prickles also occur, so that the whole surface of the plant is dangerously armed with pointed needles, some large, some extremely fine and very difficult to pick out of the skin once they have inflicted an wound.

The most deadly bristles are those which are found in the Nettles (Bichuty—*Fleuria interrupta*). They are called **stinging hairs**. They are formed of single long epidermal cells with a swollen base and a gradually tapering apex. The very tip, however, is not pointed but slightly swollen and bent to one side. The hair is stiff and elastic and the end is brittle. When it comes in contact with the skin of an animal growsing on the plant the terminal part falls off and the oblique lancet-like pointed end, now exposed, easily penetrates the skin and pours a very irritating poison (formic acid). A very painful sensation, as if of *burning*, is produced, and the part wounded becomes inflamed. Grazing animals carefully avoid plants furnished with stinging hairs, and do not let their nostrils, nor the mucous membrane of their mouths get wounded by the corrosive poison.

The protection afforded by the spines is meant mostly to defend the green foliage while it is young. This is exactly the time when protection is most needed. Later on, old foliage leaves, which have grown beyond the points of the spines or prickles, may be eaten, and this does not much matter, for old leaves are not of much use to the plant; they are soon shed as a matter of course (see fall of leaves, p. 252). Stipules are often turned into spines, as in the Jujube, and prickles and thorns are often so formed that the

small leaf-bud, or axillary shoot-buds, may be protected while they are growing. So long as the young tender foliage leaves remain in this position, between two forks of the stipules or prickles, they are avoided by animals. The protection is mostly at an end when the leaves have grown far beyond the axils.

Stability of Plants.

A plant being made up mostly of soft cells, the question arises how it maintains its stiff and rigid form even when battling against wind and rain, and, in the case of the young root, against the hard and rough soil. Young leaves, young buds, flowers, root-tips, etc. are really extremely delicate organs, and yet we find them standing erect and rigid and stiff.

Turgidity.—When water is absorbed by a cell the increased pressure of the vacuole forces the protoplasm firmly against the wall, and so stretches the latter; the elasticity of the cell-wall leads to a recoil against this force and as a result the whole cell becomes rigid. A parallel is seen in the football. When air is pumped the bladder expands, but the leather-case checks the expansion, and the result is a great tension which makes the ball hard. So, too, a rubber tubing, which is soft and pliant, when closed at one end and air pumped through the other end, becomes soon a straight and stiff rod. This phenomenon is known as *turgidity*, and the stiffened cells are called *turgid*. It takes place in all living parenchyma, and is necessarily absent in cells whose walls have lost their elasticity, such as the fibres and vessels, and also in cells without protoplasm. The turgidity of the cells of a living parenchyma is increased by the tendency of the hard bundles and tough epidermis to compress the swollen parenchyma,

so that a whole organ, such as a young root, stem, leaf, etc., becomes rigid and firm. All tender organs, such as young tendrils, foliage and floral leaves, young roots, and so on, especially aquatic plants, which have no special hard tissue to perform the mechanical function of support and rigidity, owe their stiffness to turgidity. If this is lost, as when the organ loses too much water, it droops or withers for its cells are now soft and flaccid.

Tissue-tension. All young growing organs are stiff and brittle, not because they have any hard brittle cells, but because of the extreme turgidity of the cells and of a state of great tension between the pith and the epidermis. Young organs do not develop the lignified tissues while they are fast-growing, but the pith is highly extensible; it tries to expand on all sides, especially lengthwise, and the cortex is not so extensible, much less the epidermis. The result is that the expanding pith is kept in check by the outer tissues, is compressed by the epidermis which in its turn is kept fully stretched by the pith. A tension is thus produced, and the organ in which this *tissue-tension* prevails is rendered stiff. Tissue-tension may be compared in a way with turgidity. In a turgid cell the resisting layer of the cell-wall compresses the protoplasm which has a tendency to expand under the pressure of the water of the vacuole. Between the two there is a state of tension and the result is that the cell is stiff. So in a young stem the epidermis forms the outer resisting layer, so does the cortex with its small cells, but the pith consists of thin-walled large parenchyma cells which remain highly turgid and extensible. Between the outer and inner tissues there is a state of tension, and the result it that the organ is stiff.

Tissue-tension may be easily observed in all rapidly growing herbaceous stems where it plays the most important

part of maintaining the rigidity of the organ. Young tendrils, young flower-stalks, growing parts of plants, are stiff and brittle mainly because of tissue-tension. In mature organs there is no tissue-tension because all the cells are grown up, the old pith is not so extensible and the harder tissue of the stele somewhat negatives the tension.

Tissue-tension may be demonstrated in this way. A grown up seedling of Sunflower or Cucumber is floated in water contained in a saucer. It is then cut up into pieces of 1—1/2 inch in length. Each is then split through the middle into two longitudinal halves. It is at once observed that the pith-side of each half is deeply convex, and the outer epidermis-side is deeply concave, each half being curved like a bow. This is due to the fact that the cells of the pith now exposed become greatly stretched, and since they are attached to the almost inextensible epidermis, a curvature is produced. The pith may also be separated from the stem, but for this purpose a grown up young Sunflower stem is preferable. The pith is bored out by means of a cork-borer, and it is then again inserted into the hole. It is then seen that the pith projects from the cut surface of the stem. It becomes narrower and longer than the original pith of the intact stem.

Mechanical Tissues.

The rigidity of a plant is secured by certain mechanical or strengthening tissues and cells, for turgidity and tissue-tension, though effective in young growing organs and in aquatic plants, are of no use in grown up organs. Such organs can not maintain their stability depending on turgor and tissue-tension alone, for they are subjected

to varying conditions of the soil and the atmosphere and are not surely amply protected from the drying influence of the air. Hence special strengthening tissues are developed in them. These are.—

1. **Collenchyma.**—This is a tissue consisting of live parenchyma cells which have strongly thickened walls. It occurs in all herbaceous stems which grow for a long time, in tendrils, in flower-stalks, etc. The thickening is greater at certain parts, especially at the corners (fig. 296), so that food matters and water may easily pass to and from through the unthickened parts of the cell-wall, while the thickened parts enable the tissue to undergo great flexions without rupture. The large deposition of cellulose on the cell-wall thus serves a two-fold function: (1) to prolong growth, and (2) to withstand bending strains. See also pp. 183 and 212.

2. **Sclerenchyma.**—This is a dead tissue which forms the hard bony skeleton of plants (pp. 184, 213). The long, pointed, thick-walled, often lignified and hard cells may be likened to a long steel needle. Both are highly elastic, returning to their upright position after a few vibrations when bent considerably. The tissue occurs in plants in the form of very long strings. Its sustaining strength has been estimated to be equal to that of the best hammered steel. A string of sclerenchyma may also be likened to a steel cable made up of twisted iron wires. For, the cell-wall of the fibres is made up of thin narrow strips woven together as in a cotton fabric.

Sclerenchyma occurs either as isolated strings in the ground tissue, or in conjunction with the vascular bundles. Monocot stems which do not produce wood depend entirely upon this tissue for their support. The long stems of Palms, Bamboos and Grasses are traversed by very strong strings of sclerenchyma which not only give to the plants their wonder-

ful elasticity but also enable them to bear the enormous weight of the foliage and fruits at the top. The fibres derived from plants for cordage (Palms, Agave, Jute) are sclerenchyma. The bast fibres of the phloem and the wood (fibrous tracheides) of the xylem are sclerenchymatous.

The sclerenchyma tissues are often arranged in such a way that the best mechanical advantage is secured. Thus, they often form, along with the vascular bundles, mechanical struts or girders like the iron joists which support the roof of a building. In cross section such a girder is seen to be I-shaped with the upper and lower plates of sclerenchyma and the vertical plate of vascular bundle. In this arrangement not only is the vascular bundle protected from tearing stress but the whole organ is made rigid, as if a microscopic iron joist is inserted in the soft ground tissue (see p. 237). In the stems of many plants which do not produce a bulky wood the sclerenchyma forms a T-shaped girder occurring as a transverse plate outside the vascular bundle (see fig. 302, the shaded part of each bundle is sclerenchyma, the dark part is the vascular portion, and fig. 309). Two such girders occupying opposite positions on the same diameter of the stem form a composite I-girder, as can be easily understood from the figures.

CHAPTER XXI.

ABSORPTION OF FOOD.

The Food of Plants.—Chemical analysis of the plant body tells us what substances enter into its composition. If we heat a seed or a plant there is a great loss in weight due to loss of water, and if we further burn it great volumes of gas are disengaged and an insignificant quantity of *ash* is left behind. The gas on analysis will be found to be mainly water-vapour and *carbon dioxide,* the gas which we get in ærated waters. The ash contains various salts, such as carbonates and phosphates of potash and lime. As a result of hundreds of experiments it has been found that the following elements are always present in plants :—*Carbon* (C), *Hydrogen* (H), *Oxygen* (O), *Nitrogen* (N), *Sulphur* (S), *Phosphorus* (P), *Potassium* (K), *Magnesium* (Mg), *Calcium* (Ca) and *Iron* (Fe). Occasionally other elements, such as sodium, silicon, chlorine. etc., also occur.

Composition of the Air and the Soil.—Air is a mixture of oxygen and nitrogen along with small quantities of carbon dioxide (CO_2) water-vapour (H_2O), and other gases. Of these oxygen and carbon dioxide are essential to plants, the rest are not of much importance. If we char a plant a black mass of charcoal is left behind. This is carbon, the sole basis of the organic substance of the plant. It is derived solely from the atmosphere in the form of the gas carbon dioxide.

Soil is made up of small particles formed by the gradual denudation of various rocks, and contains all the elements necessary for plant-nutrition in the form of salts. Its particles are rather loose and amongst them are little spaces occupied by air and water. In addition to these *inorganic* constituents there are remains of animals and plants, called *humus,* which by decomposing produce various acids which

break up the particles of soil or dissolve them in the water saturating the soil. This water consequently is not pure but holds in solution most of the salts useful to plants. These are—

NAME	SYMBOL	ELEMENTS PRESENT
Gypsum ...	$Ca\ SO_4$ ...	Calcium, Sulphur, Oxygen
Sodium Sulphate ...	$Na_2\ SO_4$ ...	Sodium, " "
Magnesium sulphate ...	$Mg\ SO_4$ ...	Magnesium " "
Calcium nitrate ...	$Ca\ (NO_3)_2$	Calcium, Nitrogen, "
Potassium ...	KNO_3 ...	Postassium, " "
Calcium phosphate ...	$Ca_3\ (PO_4)_2$	Calcium, Phosphorous "
Magnesium phosphate ...	$Mg\ H\ PO_4$	Magnesium " Hydrogen "
Chlorides of Sodium Magnesium, Potassium, and Iron	$NaCl$, $Mg\ Cl_2$, KCl, $Fe\ Cl_3$	Chlorine, Magnesium, Potassium, Sodium, Iron

Water-culture experiments enable us to ascertain: (1) what elements are essentially necessary for healthy growth, (2) in what form they can be best taken up, and (3) what particular nutritive function these elements have. In these experiments small quantities of salts mentioned above are dissolved in pure water, and seedlings reared on wet saw-dust are cultured in this *nutritive solution* (culture-solution). From the table it will appear that there is no mention of carbon and yet when a plant is kept in a culture-solution, as shown in fig. 320, it grows vigorously. This shows that carbon is not derived from the soil but from the atmosphere where it is present in the form of carbon dioxide gas. The whole appa-

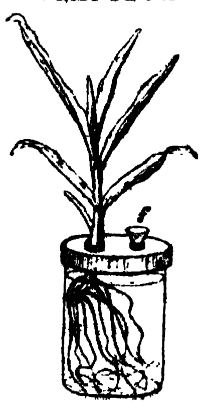


Fig. 320. A Grass plant grown in culture solution—f, the funnel for pouring fresh solution or water as it gradually decreases.

ratus (fig. 320) may be placed on a shallow saucer containing dilute potash and covered by a bell-jar resting on the saucer. In this way an atmosphere freed from carbon dioxide (the potash absorbs the carbon dioxide gas of the atmosphere) is secured and the plant is allowed to live in it. It will be noticed after a few days that the plant turns yellow and then dies, inspite of the presence of all the other necessary substances in the nutritive solution. This shows that atmospheric carbon dioxide is indispensable to plants.

A good culture-solution may be made up as follows :—

Water	4 litres.
Calcium nitrate	2 grams
Potassium nitrate	·5 gram
Magnesium sulphate	·5 ,,
Potassium phosphate	·5 ,,
Iron phosphate	a trace only

Small plants or seedlings allowed to grow in such a solution will develop into full-sized plants with flowers and even fruits, provided certain precautions are observed. The effect of omitting some of the constituents from the culture solution is detailed below :—

OMIT	EFFECT
Iron salt ...	Chlorophyll not developed, leaves become yellow, the plant dies.
Potassium salt ...	Plant becomes stunted, growth is not normal, death follows in a short time.
Calcium salt ...	Plant becomes deformed, duration of life shortened.
Magnesium salt ...	Almost same as that for potassium.

Absorption of water from soil.—That the youngest roots and their root-hairs absorb water from the soil may be shown by a simple experiment. We take a plant which is being cultured artificially by the water-culture method

and add some powdered *eosin* to the water. The water is coloured red. After a few hours the plant is taken out of the culture bottle and washed rapidly in water. It is then observed that the young roots, especially the root-hairs, are stained red both externally and internally. Trying the same experiment with powdered *carmine* (another red colouring agent) which is not soluble and hence remains suspended in the water, no colour will be noticed in the root. This shows that solid matter, however fine, can not be taken in by roots; it must be first dissolved in water. If leaves, stems, or other parts of a plant are immersed in the eosin solution, they are not coloured. This shows that the cuticle does not allow the passage of water into the cells. The part of the plant which absorbs water from the soil is only the hairy region of the root.

How minerals are dissolved.—All the constituents of the soil are not soluble in water; but most are dissolved by acid substances which are formed by decaying organic matters present in the soil. The phosphates, for instance, are indispensable to plants, but they are insoluble in pure water and soluble in acid water. Roots respire carbon dioxide and this dissolving in water forms an acid solution in the soil. Young roots and root-hairs also excrete a kind of acid substance and this also helps the solution of soil-constituents otherwise insoluble. If the root of a plant be made to grow on a slab of slate or marble, it gradually corrodes the surface of the marble which then looks as if etched along the route of the root. The etchings follow the ramifications of the root and are due to the dissolving action of the acids secreted by the root.

Osmosis.—Root-hairs are tubular cells of the young root epidermis and contain protoplasmic matter. They go into the interstices of the soil and adhere to its grains partly by capillarity and partly by their acid excretion. This acid

dissolves a part of the soil particles, and the dilute nutrient solution which is thus prepared surrounds the particles as a thin film. With this the root-hairs come in very intimate contact. This water, or rather solution, is termed the **hygroscopic water** which alone is absorbed by the roots, the superfluous water which saturates the soil and flows freely through it is of no use to plants. A soil apparently dry may sustain plant-life, for the hygroscopic water is held between the particles of soil with great tenacity. And, conversely, a soil which is physically wet may be physiologically dry, such as sand, which can not sustain plant-life for the sand grains can not stick to the root-hairs.

The way in which the hygroscopic water enters into the root-hairs will be understood from the following experiment (fig. 321). A wide glass tube (A) is closed at one end by a piece of a parchment paper (a) and the other end is corked. It is then filled with a strong solution of sugar coloured with ink or magenta, and a manometer tube (M) is then attached to it by means of a short tube which passes through a hole in the cork. The manometer contains mercury and the part of the tube between the mercury and the wide tube (A) is previously filled with the same sugar solution. The glass tube is then placed in a beaker (B) containing pure water. After a short time it will be noticed that the mercury which at the beginning of the experiment had the same level in both limbs now rise steadily in the narrow tube, a little depression in the level of mercury of the bulb (M) having also taken place. The pressure which causes the ascent of the mercury in the experiment is termed **osmotic pressure** and the phenomenon is known as **osmosis.**

The principle of osmosis is this ; if there be a difference in concentration of two solutions on the two sides of a porous membrane, diffusion takes place in such a way that

the stronger solution becomes dilute and the weaker one concentrated; ultimately equilibrium is established when the concentrations on both sides are equal. The explanation of the above experiment is this: the parchment is a semi-pervious membrane. On one side of it, within the tube (A), there is a thick solution of sugar, and on the other, in the breaker (B), is simply water. The sugar solution passes out into the water of the beaker—this is seen from the water in B being gradually coloured. But much more quickly and strongly does the water of the beaker pass through the parchment and enter the glass tube, and hence the pressure. The osmotic pressure can be measured by the rise of the mercury column; it remains active so long as there is any considerable difference in the concentrations of the two liquids. In osmosis there is a diffusion of two liquids through a separting porous membrane; the rate of diffusion of the lighter solution (*endosmosis*) is far greater than that of the denser solution (*exosmosis*).

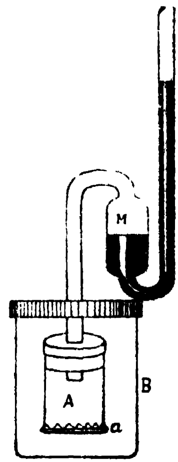


Fig 321. Apparatus for showing osmosis.

The glass cylinder in the above experiment may be taken to be a root-hair. the parchment then representing the cell-wall. Outside the root-hair there is a very dilute nutrient solution, inside it a dense protoplasm and a concentrated cell-sap. The dilute nutrient solution consequently passes into the root-hair by osmosis, almost in the same manner as the water of the beaker passes into the tube. All solutions, however, do not pass through permeable membranes. Colloides are those substances which form solutions incapable of passing through such a membrane;

protoplasm and most of the albuminous substances are of this nature. Inorganic salts, such as those present in the soil, are on the contrary crystalloids, that is, they form solutions which can pass through permeable membranes.

The sugars are also crsytalloids so that they too can readily pass through permeable membranes. In the case of the root-hair the protoplasm and the proteids which enter into its composition being colloids cannot come out of the cell, but the cell-sap contains acids which are crystalloids and come out by exosmosis and help the root to prepare the nutrient solution by dissolving those particles of the soil which are insoluble in water. The nutrient solution present about each root-hair being a very dilute solution rapidly passes into the cell by endosmosis. Thus the root absorbs from the soil not only water but also a part of the earth which is necessary for the life of the plant.

To see osmosis, take the bladder of a fish, Wash it thoroughly and then fill it with a strong solution of salt or sugar. Tie the open end so as to make it water-tight and then place the bladder in water. In a few hours it becomes hard and rigid, just as when a football is pumped hard. Now take the bladder out and place it in a solution of salt or sugar thicker than the last. In a short time the bladder loses its stiffness and becomes soft. In the first case water enters into it, in the second, the solution comes out of it ; in both cases the lighter liquid flows towards the stronger one.

SUMMARY.

By chemical analysis it is found that the following ten elements are always present in the plant body : C, H, N, O, S, P, Mg, Fe, K, Ca. Water-culture experiments show that these elements excepting carbon, are derived from the soil in the form of salts, and the carbon is derived from the air in the form of carbon dioxide.

The way in which these salts are taken in by plants is this ; Some of the salts present in the earth are soluble in water, others are insolu-

ble, but they are dissolved by the acids secreted by the young root-hairs. This dilute NUTRIENT SOLUTION of the plant is held with great tenacity by the fine particles of sand of which the earth is composed. With these particles the fine root-hairs come in intimate contact, in fact the particles stick to the hairs because of the acid secretion. The water then passes into the root-hairs by OSMOSIS. Osmosis is the phenomenon of diffusion of fluids through a permeable membrane and inside the cell is a concentrated cell-sap, outside it the very dilute nutrient solution. The later consequently rapidly passes into the cell. The protolasm and the more complex cell contents can not come out, being colloids, but a small quantity of the acid cell-sap comes out by exosmosis and this helps to dissolve the particles of soil and prepare more nutrient solution.

QUESTIONS.

1. What are the essential foods of plants? How would you determine them?
2. What is Water culture and what do you learn from it?
3. What is Osmosis? Describe a simple experiment you have seen to demonstrate it.
4. How do plants absorb food matters from the soil?
5. What is hygroscopic water? What are crystalloids and colloids?

CHAPTER XXII.

CONDUCTION OF WATER.

As all living cells require water for various purposes it travels in the plant body in various ways. The cortical cells, especially of the root, are always living cells. Like the root-hairs they also have a great capacity for imbibing water by osmosis. For, in this respect what the root-hairs are to the hygroscopic water of the soil, the inner cortical cells are to the root-hairs. The cortical cells have a dense cell-sap, while just touching them on the outside are the root-hairs containing a large quantity of water. Consequently the lighter solution of the root-hairs moves towards the cortical cells. Thus, by a ceaseless process of osmosis water moves from cell to cell, from the soil to the root-hairs, and from the latter to the cortex, and thence to the xylem of the root.

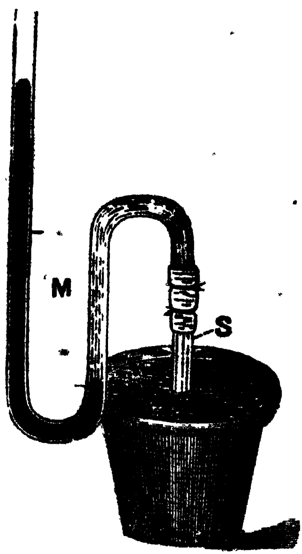


Fig. 322. Apparatus demonstrating root-pressure.

Root-pressure. Most plants when cut off a little away from the ground in early spring exude water from the cut surface. The water is evidently pressed upwards by the root. The power which the root possesses of forcing water upwards is known as *root-pressure*. The exudation increases if we warm the roots, decreases if we cool them.

Owing to the great excess of endosmosis a considerable

pressure is set up in the cortical cells of a root. By virtue of this pressure water is pumped into the xylem vessels, and when the rate of absorption by roots is greater than the rate of loss by the leaves, water is forcibly pumped up the xylem tissues. This explains the cause of root-pressure. Fig. 322 shows a method of demonstrating and estimating the root-pressure. A pot plant is cut off, early in the morning, a little away from its base. To the stump (S) is attached a bent glass tube (M) by a piece of rubber tubing. The glass tube is previously filled partly with mercury. After some time the mercury in the open limb rises ; from this the force of root-pressure can be ascertained.

By virtue of root-pressure drops of water are actually ejected from the margins and tips of many leaves especially at night and early morning. This is observed in the leaf-tips of Kuchoo and other Aroids, several grasses and herbaceous plants such as the garden Nasturtium, (fig. 73) etc. The copious outflow of a sweet liquid from the cut surfaces of Date palms, Toddy palms etc., is also due to root-pressure.

Fig. 323. A drop of water ejected from the leaf-tip of Kuchoo.

Transpiration.—The leaves of plants are constantly giving off water in the form of vapour especially as long as they are in light. This can be proved by placing a pot plant under a bell-jar. After a short time the inside of the jar is found to be dimmed with moisture. The process really goes on in all green aerial parts of plants and is known as ***transpiration.*** It is not a simple process of evaporation ; for evaporation is not much affected by the presence or absence of light, but transpiration takes place mainly in light. Thus, if a plant be covered with a bell-jar at midnight little mois-

ture will be found deposited on the glass. This shows that during daytime water is rapidly given off by the leaves in the form of vapour. The total volume of water thus lost by a plant is very great. For instance, a strong Sunflower plant, of about the height of a man, loses in a warm day over 5lbs of water. It has been estimated that an acre of Cabbage plants will transpire two million pounds of water in a month! The water vapour escapes either through the outer walls of the epidermis, or through the stomatal openings in it. The former is called *cuticular* transpiration, and the latter *stomatal* transpiration. Both processes go on in ordinary land plants, but in plants possessing a thick cuticle the cuticular transpiration is small and may be altogether absent. It is especially strong in herbaceous shade plants and in very young leaves which have not yet developed a thick cuticle and a sufficient number of stomata. Stomatal transpiration is of course more important of the two, for stomata are the special organs of transpiration.

Importance of transpiration.—(1) Roots of plants absorb a large quantity of water, for the nutrient solution prepared in the soil is very dilute. If it is strong the salts cannot go into the root-hairs by osmosis and a large quantity of water is absorbed. The water, however, acts more as carrier of the minerals than as food, and after having reached the leaves deposits the salts and goes away as vapour. The excess water is transpired. Hence transpiration is essentially necessary not only to supply every organ with water when it is required, but also to maintain a steady stream so that the leaves, the main manufactory of the plant, may have a continuous supply of raw food-matters (the salts) from the soil. (2) Moreover, as plants are exposed either to direct or to diffuse sunlight, they would become excessively heated if not cooled by transpiration. By saturating every living

organ, and by being constantly vapourised, the transpired water helps to keep the delicate organs of plants cool; the energy of the sun's heat is expended in converting liquid water into vapour and is thus diverted from overheating the plant. (3) Again, by transpiration the ascent of water in plants is facilitated. For, as the leaf continuously loses water its component cells become relatively dry and have an increasing tendency to suck up water from the stem or from the vascular bundles. By virtue of this suction action of the foliage, water is rapidly pumped up the stem, and thus a speedy circulation of food matters throughout the plant is ensured.

The fact that water is given off by the leaves may be shown by holding a piece of cobalt chloride paper near the lower surface of a leaf (where lie the stomata) when after a short time the blue paper will turn red. A paper soaked with cobalt chloride solution has at first a reddish tinge but when it is dried near a flame it takes a blue colour. This blue paper will indicate the presence of moisture by being turned red.

Stomata are the special organs of transpiration, for the water-vapour is formed in the respiratory cavities (fig. 310) by the heat of the sun, and the stomatal openings allow its escape. The mechanism of the stomatal apparatus is exquisitely adapted to modify transpiration. The guard-cells are living cells containing protoplasm which is highly sensitive to light-stimulus. When light falls upon the guard-cells they absorb a quantity of water from the neighbouring cells and become turgid. Turgidity makes them stand erect leaving the stomatal passage open. The increased demand of water on the part of the guard-cells is due to the fact that their protoplasm prepares, under the influence of sunlight, a certain quantity of sugar. This substance renders the cell-sap denser and hence by osmosis water is taken up. At night the protoplasm cannot prepare any sugar and so the turgidity gradually diminishes, and then the guard-cells become flatter and close the orifice. Hence at night, or in absence of light, transpiration cannot go on for the simple

reason that the stomata are all closed. The structure of the leaf is such that transpiration takes place easily. For, not only are leaves flat and thin and expose the greatest surface but they are also amply provided with stomata and respiratory cavities, and the veins or vascular strands ramify in all directions. Green stems also transpire being provided with stomata, but a woody stem scarcely transpires at all.

The reason why leaves do not transpire at night is this: when there is no sunlight the raw mineral food taken from the soil cannot be cooked up into plastic material and so the work done in carrying the water to leaves is so much loss of energy. Besides, a continuous loss of water at night would have a chilling effect under which the protoplasm might die. And further, the guard-cells being closed at night there is no outlet for the water-vapour. Besides light which is essential, there are several other factors which influence the rate of transpiration :—

(1) *Temperature of air.*—The higher the temperature the greater the transpiration, evidently because the heated plant gives off vapour more quickly.

(2) *Moistness of air.*—A dry atmosphere favours transpiration for obvious reasons.

(3) *Movement of air* also hastens transpiration. A hot windy day often causes plants to droop or wilt.

Ascent of water—In small herbaceous plants the ascent of water is due, in the first place, to the continuous endosmotic action of the root-hairs, and secondly, to the great hydrostatic pressure exerted by the cortical cells on the stele of the root whereby the vessels of the xylem become filled with water. This root-pressure is sometimes very great and can explain how water rises in plants. In large plants, however, the distance over which water must travel in order to reach the leaves and growing points is so great that root-pressure can not be regarded as the cause. In them

transpiration, perhaps more than anything else, is responsible for the ascent of water. The loss of water by the mesophyll cells occasions a great concentration in their cell-sap and thus they obtain the power of sucking up water from the xylem. The latter may be regarded as made up of long chains of cells, the end cells being in intimate contact with those of the mesophyll. These losing water to the atmosphere take it up from the first layer of cells of the xylem. The latter in their turn suck water from the next layer of cells; in like manner every cell of the xylem-chain may be regarded as standing to that just below it in the same relation as the mesophyll cells stand to the xylem—each of them sucks water from below.

By the united action of all these sucking cells a considerable suction is brought into play and this immediately causes the ascent of a current of water, termed the **transpiration current.** Thus root-pressure pumps water into the xylem; transpiration helps it to ascend. The action of transpiration may be compared to that of a suction pump.

Transpiration takes place only in light and it is more active on a windy or a dry day. Under active transpiration there is no direct evidence of root-pressure. For, if an actively transpiring shoot be cut off from near the ground and the cut stump attached to the manometer, as shown in fig. 322, it will be found that there is no exudation of sap and that the mercury in the open limb of the manometer (M), instead of rising, falls, thus indicating a *negative* root-pressure. This is because the suction by transpiration is greater than the pumping action of the roots. If, however, transpiration be checked by covering the plant, for instance, with a bell-jar for some time before cutting, the cut stump will exude water and evidence root-pressure. Thus transpiration and root-pressure supplement each other: when the atmosphere is dry or windy or otherwise favourable to

strong transpiration the suction action reaches even the roots and water travels to the upper regions where it is dry and hot, just as cold air is drawn up by a heated land-scape. When the day is moist and transpiration is prevented or checked, water is equally pumped up by root-pressure. At night no transpiration is possible but the root-hairs are active all the same, and so a considerable quantity of water accumulates in the xylem tissues by root-pressure. When this is very great an actual exudation of drops of water from the leaf-tips may take place. Thus is secured by root-pressure that giving off of the excess water not required by the plant which is one of the objects of transpiration. As the sun rises and the day warms up, transpiration now comes into operation and root-pressure is diminished; gradually it is entirely negatived by transpiration. By coating the leaves with wax (thus plugging the stomata and preventing transpiration) and warming the roots, however, active exudation of water may be observed even when the day is hot and otherwise conducive to excessive transpiration. Or a cut twig may be attached to a bent glass-tube, as shown in fig. 324, filling the short limb previously with water and a little mercury; on pouring mercury now into the longer tube the water is forced up the stem by pressure and exudes in drops from the tips and margins of the leaves.

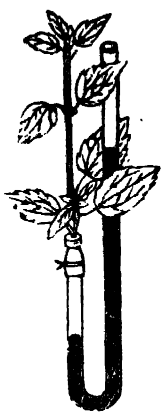


Fig. 324. Apparatus for showing the exudation of water from cut shoots under pressure.

The force of suction brought about by transpiration may be shown in this way.—The stem of an actively transpiring plant is bent and brought under water contained in a basin and there cut. It is immediately fitted tightly into a long glass tube brought under the water, and the cut shoot with

the tube full of water is held vertically over a trough of mercury, the free end of the tube dipping in the mercury. The leaves remain turgid and go on actively transpiring, the water being supplied by the glass tube, while a short column of mercury rises in the tube. This represents the force of suction of the transpiring organs.

The transpiration current ascends by the xylem or the wood of plants. If a ring of cortex be removed from a stem by running two parallel incisions round it, and the vascular tissues more or less exposed—this does not alter or affect transpiration at all. But if, with or without the cortex removed, the wound inflicted be deep enough to reach the wood or the vascular bundles, the leaves standing just above such injured portions soon after droop and die. It is the tracheæ and the tracheid tissues which act as the conductor of water.

SUMMARY.

CONDUCTION OF WATER or of the nutrient solution takes place—

(1) by osmosis from cell to cell,

(2) by root-pressure from the cortex to the xylem,

(3) by transpiration from the root to the leaves.

ROOT PRESSURE is the force with which water is pumped up by the root through xylem. By it water is forced to a great height of the stem.

TRANSPIRATION is the process by which aqueous vapour is given up by the green parts of a plant, especially by the foliage. Stomata are the special organs of transpiration. The aqueous vapour diffuses out through the stomata during the day when the guard-cells are open. By transpiration a great sucking force is exerted by the foliage on the xylem tissue and this causes the ascent of water.

QUESTIONS.

1. What do you understand by root-pressure?

2. Describe how water ascends in plants.

3. What is transpiration? Distinguish between stomatal and cuticular transpiration.

4. Describe carefully the course followed by water as it enters the plant from the soil and goes out by the leaves.

CHAPTER XXIII.

ASSIMILATION.

In the preceding chapter it has been shown that plants require a constant supply of water, that the water absorbed from the soil contains various salts dissolved in it, and that without some of these salts plant life is impossible. But what becomes of these salts? They are converted into organic compounds by the protoplasm, or in other words are "assimilated." Thus, the nitrates, sulphates, phosphates, etc., from the soil along with the carbon dioxide gas of the atmosphere are chemically united in the body of the plant into carbohydrates, proteids, oils and fats, and so on.

Absorption of carbon dioxide.—Of all the essential elements of plant-food (p. 273) carbon is the most important, for it forms the greater part of the plant body. It is not absorbed from the soil, as shown by water-culture experiments, but from the air where it is present in the form of carbon dioxide gas. To show that this atmospheric carbon dioxide is the only source of carbon and is indispensable to plants, we simply place a small pot plant on a shallow saucer containing water and invert a bell-jar over it resting on the saucer, so that the plant is enclosed in an air-tight space. After leaving the apparatus exposed to light for some time the air in the bell-jar is examined. It will be found that carbon dioxide has disappeared and the percentage of oxygen has increased. The experiment shows that carbon dioxide gas enters into the plant as such, and we know that the stomata are the passages through which this gas finds itself into the plant-body. It also proves that the light is required in order that the leaves may absorb the gas, and this is easily explained for the

guard-cells of a stoma open only in light. Hence light by stimulating the guard-cells opens the stomata not only for transpiration but also for the absorption of air.

If the above experiment is performed in a dark room the carbon dioxide is not absorbed, nor, if instead of taking green parts of plants, such as leaves, we take only flowers, or roots, or other non-green parts. These experiments show that *only green parts of plants can absorb carbon dioxide* and that *light is indispensable.*

This atmospheric carbon dioxide passes through the stomata to the spongy tissues of leaves, and there meeting the large surplus of water in the respiratory cavities and that saturating the cell-wall, gets dissolved to form a dilute solution. This solution is then absorbed by all the mesophyll cells exactly in the same way as the water in the soil comes into the root-hairs, *i.e.*, by endosmosis. The protoplasm of the mesophyll cells then "assimilates" the carbon; *i.e.*, retains it to form starch and such things and lets go the oxygen. Thus in carbon assimilation oxygen is set free. This can be shown by a simple and interesting experiment.

Fig. 325. Apparatus showing evolution of oxygen from a plant in light.

Take a glass beaker and put in it a cut portion of the common water-plant Chara with sufficient water. Tie a load to the plant so that it is kept submerged, not floating, and leave the whole in sunlight. It will be noticed that bubbles of gas escape from the cut end of the stem. It is easy to count the number of bubbles, and comparing the numbers when the apparatus is placed in direct light, or in diffused light, or in comparative darkness the rate of assimilation as it is influenced by light may be roughly measured. That the gas evolved is oxygen may be shown by collecting it as

shown in fig. 325. A funnel covers the plants so that the gas bubbles all collect in the funnel and come out only through its stem. The funnel is wholly submerged and a test-tube filled with water is inverted over the funnel-stem. The bubbles run up the test-tube and collect at its top displacing the water. The gas may be examined chemically and the fact that it is purely oxygen proved.

Carbon assimilation then is simply this: light by opening the stomata allows the atmospheric gases to diffuse into the spongy mesophyll tissues where they dissolve in the water saturating the cells and passes into them by endosmosis. Once inside the cell, in contact with the protoplasm, the gas solution is at once altered, the carbon of the carbon dioxide is assimilated, and the oxygen is given back to the air. Being not required in the cells the oxygen is driven out by exosmosis, collects in the inter-cellular spaces, and goes out by the stomata as rapidly as the carbon dioxide comes in. Thus is maintained in the leaves a steady stream of a carbon dioxide coming in and oxygen going out, and this so long as there is light.

Conditions essential for carbon-assimilation are :—

1. *Light*—The absorption of carbon dioxide and the evolution of oxygen increases gradually as the intensity of light increases to a certain degree. This can be shown by placing the apparatus (fig. 325) in different positions, at one time in direct sunlight, at another in diffused light, and then in very dull light or darkness. Intense light, however, acts injuriously on plants, for it decomposes the chloroplasts, and so does prolonged darkness. Light only of moderate intensity is what is required by the plant.

2. *Heat* is also required. If the water in the experiment be cooled by placing the beaker in ice the evolution of gas bubbles ceases; warming the water gradually increases it. Hence a suitable moderate temperature is essential.

3. *Chlorophyll* is also essential, for only green parts of plants can assimilate carbon. And since chlorophyll is developed chiefly in foliage leaves, the latter are the assimilating organs of plants.

4. *Water* and the *nutrient solution* are of course necessary. For, the nutrient solution absorbed from the soil and sent up to the leaves contains iron and potassium salts and these are essential. Without iron chlorophyll cannot be formed, and when an iron salt is not supplied the chloroplasts become yellow and functionless. The function of potassium salts is not clearly understood but its absence markedly diminishes the assimilatory process.

Plants grown in darkness become yellow and sickly; they are said to be *etiolated*. This is due to the fact that in darkness chlorophyll is not formed or is destroyed inspite of the presence of iron salt. In the absence of chlorophyll there is no assimilation and the plant ultimately dies.

Many Algæ, Mosses, and young Fern plants can produce chlorophyll in darkness, so likewise many seedlings of higher plants: thus the embryo of the Morning-glory and of other plants of the family has green cotyledons even while it is still enclosed in the seed.

Photo-synthesis.—The process whereby carbohydrates are found in plants under the influence of light is termed *photo-synthesis*. It is the same as carbon-assimilation. By this process carbon dioxide is absorbed, carbon is fixed, oxygen is evolved, and a carbohydrate is formed in the chlorophyll containing cells of a plant. The chemical changes which take place are these: water and carbon dioxide coming to the chloroplasts of the mesophyll cells and under the influence of light, become combined into a very unstable substance, termed *formic aldehyde* (CH_2O) as represented by the chemical equation— $CO_2 + H_2O = CH_2O + O_2$ and the oxygen (O_2) is evolved in the gaseous form. This,

however, is only a hypothesis. All that can be experimentally shown is that a simple carbohydrate, a sugar having the formula six times that of the formic aldehyde, *viz.*, $C_6H_{12}O_6$ can be detected in many cases. But the final product of carbon-assimilation is generally, starch ($C_6H_{10}O_5$) which may be regarded as a very condensed and insoluble form of the sugar first prepared by the chloroplasts. In certain plants even cane-sugar ($C_{12}H_{22}O_{11}$) has been detected in the leaves. Disregarding the simpler and intermediate chemical changes in the chloroplasts, the final result of photo-synthesis, as evidenced by the almost universal presence of starch, in leaves may be represented by the chemical equation— $6\,CO_2 + 5H_2\,O = C_6H_{10}O_5 + 6O_2$

Starch is the first *visible* product of assimilation. It must be regarded as a condensed form of the sugar which are undoubtedly formed in the chloroplasts, for the simpler sugars have the formula $C_6\,H_{12}O_6$ and by subtracting one molecule of water (H_2O) and multiplying the complexity of the molecules the formula for starch is obtained— this is $(C_6\,H_{10}\,O_5)_N$. The starch formed in the mesophyll cells exists in very minute grains and has but a transitory existence. It is continuously dissolved into sugar and in this form is transported from the leaves to the various parts of the plant. Hence this starch is termed *assimilation starch*, as opposed to *reserve starch* formed by the leucoplasts as large grains in reservoirs of food matter (cf. pp. 193-5.)

The formation of starch by photo-synthesis may be demonstrated in this way. A plant (Sunflower, say) is left in the open sunshine for some time. A leaf is then plucked and left in hot spirit for a short time. The alcohol extracts the chlorophyll and becomes coloured green, the leaf being at the same time decolourised and whitened. It is then washed in water and then placed in a dilute solution of iodine when the leaf gradually assumes a dull black or dark blue colour. This is the iodine reaction of starch. The same experiment may be tried with different leaves, some more or less exposed to light and some remaining in the shade. The latter would take a beautiful blue colour ; the former a

dull black colour as above. This shows that in leaves directly exposed to light the amount of starch is greater than in one lying in the shade. Again, if a plant be kept for a day or two at a stretch in a dark room and then its leaves examined with the iodine test, after being decolourised in warm spirit, they will take up only a yellow colour which indicates that there is no starch but only proteid. The same plant placed for a few hours in sunshine will show the presence of starch in its leaves. An interesting experiment in this connection is to take a pot plant (Sunflower, say) and paste thin strips of tinfoil over the leaves or write over them in bold types with chinese ink. The plant is left in the open for several hours and then the leaves written or pasted over are taken and washed and decolourised with hot spirit. On being placed in iodine solution the exposed portions only become blue ; the parts covered by the tinfoil or ink remain colourless and almost transparent, showing the absence of starch.

Fig. 326. Leaf covered with tinfoil with letters cut out showing formation of starch in light.

So long as plants get light their leaves actively transpire and absorb carbon dioxide from the atmosphere. Their cells got all the necessary raw materials and then these under the influence of light and chlorophyll prepare starch and other things. At night or in dim light the starch grains are all transformed into sugar which travels in solution to the different growing parts and the underground structures. By the time the sun rises on the next day the leaves are kept clear of starch grains formed on the previous day and are

ready for assimilation once more. Fig. 327 is a simple apparatus by which it can be shown how air gets inside the leaves. A leaf is fitted into an india-rubber stopper which fits into a bottle containing water. The petiole dips in the water and the stopper is provided with a bent glass tubing by which the air inside the bottle can be sucked out. In the act a number of air bubbles escape from the cut end of the petiole and rises through the water. The experiment proves that air can freely pass from the atmosphere into the leaf. If, however, we paint the surface of the leaf with vaseline the suction of air through the open tube, however hard, does not occasion a similar evolution of gas from the cut end. This is because the vaseline plugs the stomata and so prevents the passage of air. If the same experiment is performed at night or with a withering leaf the bubbles do not appear. This shows that air can come within the leaf only when the stomata are open, and that a fresh healthy leaf and sunlight are necessary for the passage of atmospheric gases.

Fig. 327. Apparatus to show that air can pass into the plant.

Why light is essential for photo-synthesis.—In the first place without light chlorophyll is not formed and the stomata do not open for the entrance of air; transpiration does not take place and so the mesophyll cells, the factory of the plant, do not get the constant supply of minerals essential for nutrition. And secondly, light is absorbed by the chloroplasts and gives them the necessary energy required for the starting of chemical changes. A part of the solar energy transmitted in the form of light is absorbed by the

chloroplasts and this is transformed into heat which is required to tear up oxygen from the carbon of carbon dioxide. For the decomposition of carbon dioxide some energy is required, also for uniting the carbon (C) with water (H_2O) to form the hypothetical CH_2O or the carbohydrate $C_6H_{12}O_6$, and this energy is given to the chloroplasts by the sun. Thus it will appear that the sun guides the formation of the most important plant-food, namely starch, energises the most important formative tissue of plants, namely chlorenchyma, builds up the whole plant-body, and is, in a sense, the creator of the vegetation of a country. Upon this vegetation the life of the animal kingdom collectively depends. The energy of the sun, first absorbed by the chloroplasts, is thus partly stored potentially in the plant, and it is this energy which is set free in the form of heat and light when we burn wood or coal (which is merely compressed wood), and as muscular energy in animals which have to depend upon the plant-world for food.

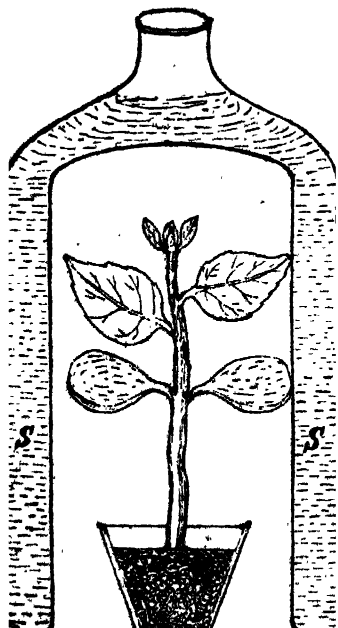


Fig. 328. Plant grown under a double-walled bell-jar containing potassium bichromate solution [S].

Chlorophyll and Light.—The pigments present in chloroplasts may be dissolved out in alcohol or ether. For preparing the solution green leaves, preferably of Grass or similar non-resinous plants are taken in quantity and cut up

into small fragments and washed in boiling water. They are then digested in cold alcohol. A deep green solution is obtained. This when held before the light appears of a bright green colour, and seen in reflected light appears dull red. This is because light consists of seven different rays or colours—violet, indigo, blue, green, yellow, orange and red. When it passes through a solution of chlorophyll the yellow to red rays are absorbed and the blue-green rays pass through; the solution appears dark green. In reflected light the rays absorbed by the solution, namely the red-yellow rays, come to our eyes. The red rays thus absorbed are known as the 'heat rays'; they heat the chloroplasts but on being absorbed are transformed into some form of chemical energy leading to the decomposition of carbon dioxide and formation of carbohydrates. The yellow-red rays are the only part of sunlight which is essential for assimilation. To show this double-walled bell-jars are used. These are large bottles (fig. 328) without the bottom, having a hollow wall which can be filled up with liquids from the stopper. Bichromate of potassium dissolves in water to form a red or reddish-yellow solution which allows the red, orange, and yellow rays to pass and absorbs the rest of solar light. Plants covered by jars filled with this solution assimilate almost as vigorously as in white light. Solution of cuper-ammonium oxide, however, is deep blue; it allows only the blue-green rays to pass and absorbs the red to yellow rays. Plants left in this blue light can not assimilate and soon die. Blue or green light is of little use to plants.

Nitrogen Assimilation.—By the assimilation of carbon carbo-hydrates are formed in plants. The greater part of the plant substance is made up of carbo-hydrates, such as the cellulose of cell-walls, sugars and starch which abound in plants as cell-contents. But the living, and consequently the most important substance of a plant, the protoplasm, is essentially a mixture of various nitrogenous matters or proteids. These proteids also occur, though to a small extent, as reserve food matters in plants (see p. 197). The chemical changes by which these nitrogenous substances are produced are not well understood. Besides containing carbon, hydrogen, and oxygen, the only components of carbo-hydrates, the protoplasm and the albuminous products contain a large percentage of nitrogen and small quantities of sulphur and phosphorous.

The manufacture of these very complex nitrogen compounds takes place in the roots and the leaves, and the presence of light and chloroplasts is not absolutely essential. The nitrogen is obtained almost solely from the soil in the form of nitrates of calcium, magnesium or potassium. Precisely what takes place is not known but a class of organic compounds known as *amides* is often found in leaves so long as assimilation goes on. These amides contain nitrogen besides carbon, hydrogen and oxygen, and are believed to be the first step towards the formation of the more complex proteids. Carbon-assimilation must always precede that of nitrogen, for carbo-hydrates are essential for the formation of these nitrogenous matters.

The principle of the synthetic processes taking place in plants is one of continued reduction. All the crude matters which enter the plant, either from the soil or from the atmosphere, are highly oxygenated compounds, such as nitrates, sulphates, phosphates and dioxide of carbon. With the help of solar energy the chloroplasts dislodge the oxygen from H_2O and CO_2, prepare a carbohydrate, and set free the oxygen. This carbohydrate is less stable than H_2O and CO_2 and has a tendency to combine with oxygen. When nitrates reach the chlorophyll apparatus they are decomposed to dislodge their oxygen, and a less oxidised or de-oxidised product rich in nitrogen is produced. Now it is a well-known chemical principle that substances which are less stable have the greatest tendency to unite, and thus we may conceive a union of the carbohydrates of leaves and the unstable nitrogen compound. The result of this union is an amide; similarly with sulphates and phosphates a similar process of deoxidation would result in the production of substances containing sulphur and phosphorous respectively in such an unstable state of union that they readily let their sulphur and phosphorous combine with the amides to form probably some of those things which constitute the protoplasm. By the time the protoplasmic substance is formed there must have taken place a series of reductions whereby the most deoxidised substance known—the protoplasm—is formed. It is for this reason that the chemical nature of protoplasm cannot be ascertained, its instability making it extremely elusive to a proper chemical handling.

The chief products of assimilation are :—

1. **Carbo-hydrates** (see p. 193) of which **starch, sugars,** and **cellulose** are the most important.

2. **Proteids** or albumens (see p. 197) comprising numerous classes of nitrogenous organic matters.

3. **Fats** and oils which are chiefly compounds of carbon, hydrogen, and oxygen but are much more complex than the carbohydrates, and contain a smaller percentage of oxyen than the latter. They are absolutely insoluble in water unlike sugars, starch and many proteids.

Distribution of Assimilates. So long as there is direct or diffuse light leaves prepare starch and albumens, which are of course far in excess of what could be required by them for their growth. The assimilated matter is sent to the different growing tissues and the surplus matter is stored in special reservoirs. The migration of the assimilated matters to the various parts of the plant-body takes place in solution ; for starch is a solid substance and cannot obviously pass through cell-walls, and protoplasm and proteids are colloids and consequently are incapable of diffusing through cell-walls. For transportation, consequently, all those products of assimilation, or *assimilates* as they are called, are first rendered soluble by certain bodies known as **enzymes.** The enzymes dissolve the insoluble organic compounds by decomposing them into simpler soluble forms. Starch is converted into sugars by the enzyme termed *diastase* ; the sugars dissolve in the cell-sap and by the process of osmosis pass from cell to cell. For a long-distanceed transport these sugars travel through the vascular bundle-sheath as well as through some of the parenchyma cells of the bundles. Brought to the underground parts of plants, or to other store-houses of reserve food, the sugars are again converted into starch with the help of the leucoplasts. Proteids are decomposed into simpler nitrogen compounds,

such as peptones which are highly soluble, by proteolytic or peptonising enzymes called *proteases* and are thus brought into a state of solution which reaches the sieve-tubes and are then easily transported over long distances. Sieve-tubes and their companion cells are the chief organs for carrying nitrogenous food-matters which coming to such reservoirs as underground stems and roots, seeds and fruits, become transformed into those reserved proteids mentioned on page 197.

The elaborated sap, as the solution of the assimilates travelling in plants is called, is thus conducted from cell to cell by osmosis, and transported from one extremity of the plant to another by the phloem and bundle-sheath tissues. The xylem, it should be remembered, is the tissue for the transport of the ascending or the crude sap.

SPECIAL PROCESSES OF NUTRITION.

Plants which prepare their own food—carbohydrate and nitrogenous—from raw inorganic substances are termed **autophytes.** Those which live on decaying organic matters are **saprophytes,** while **parasites** are plants which live upon other living bodies, animals or plants. All green plants are autophytes, whereas the Fungi as a class are either saprophytes or parasites. Instances of parasites and saprophytes are not rare amongst the Phanerogams (for root-parasties, see p. 25). In certain cases two plants exist together for their mutual help; they form a life-partnership and are called **symbionts,** the phenomenon of their composite existence being known as **symbiosis.**

In autophytes the most common mode of nutrition obtains—that of assimilating carbon, nitrogen and other elements with the help of green leaves. The **assimilation of nitrogen,** however, is peculiar **in plants belonging to the Pea family** (Leguminoseae). All green plants get nitrogen in the form of nitrates or ammonia salts from the soil; they can not assimilate the free nitrogen of the air. Leguminous plants, on the contrary, form an exception. They can thrive well on a soil poor in nitrogen compounds and, as a matter of fact, enrich it with such compounds. They take nitrogen from the air and *fix* it in the soil. This they do with the help of certain bacteria-like organisms pre-

sent in the soil. These organisms, bacterioids as they are called, infect the root of leguminous plants and give rise to tubercular swellings on its surface. The root-tubercles may be easily observed by digging out such a plant and washing it free from the adhering soil. The bacterioids are extremely minute microscopic bodies which penetrate the root-hairs in the form of extremely thin tubes and reaching the cortex form extensive colonies in the cells. The cortical cells are abnormally stimulated and grow out in the form of tubercles. They are very rich in starch and receive tiny divisions of the vascular bundles from the root. The bacterioids absorb the nitrogon from the air, convert it into some nitrogen compound which is readily assimilated by the plant, and in return get a safe and congenial home as well as an unlimited supply of carbohydrates. Thus here is a symbiosis. The bacterioids helping the plant with nitrogen, and the plant helping its guest with carbohydrates.

Far more extensive than the above are the symbiotic relationship which many Fungi forms with certain forest trees. The roots of such trees are commonly surrounded with a thick coat of fungal threads. Careful examination shows that these felted roots do not generally produce any root-hairs but that the work of the latter, that of absorption of nutriment, is performed by the hair-like threads of the fungus. The symbionts mutually derive great benefit from their life-partnership, for the bed of the forest is very rich in decaying leaves and organic matters which form an acid humus injurious to root-hairs and incapable of being absorbed by the plant unless first absorbed and rendered harmless by the action of the fungus. Such a symbiotic union is called a **mycorhiza.**

Another instance of symbiosis is afforded by certain plants known as **Lichens** which were formerly regarded as a distinct class, but are now known to be made up of Algæ and Fungi in intimate life-partnership. The common Lichens are those which are observed as a greenish-white incrustation on Palm trees and bare rocks. The Algæ of the Lichen being green assimilate carbon like autophytes but as they live on rather smooth surfaces the Fungi are of use in enabling them to absorb water and to remain attached to places where otherwise they could not live. The Algæ help the Fungi with carbohydrates; the Fungi help the Algæ with water and minerals and a secure position.

Insectivorous plants

Of all the various forms of nutrition in autophytes none is more remarkable than what takes place in **insectivorous plants.** Although they are green plants and quite fit to assimilate, they seem to have adopted

a special contrivance of securing nitrogenous food. They are residents of water-logged places, or places very poor in nitrogen and phosphorous compounds, and the general conditions of the soil and the atmosphere do not offer a tolerable transpiration. Consequently their leaves do not get that continuous and rapid supply of mineral salts [which alone can afford nitrogen and phosphorous] which is the rule in other green plants. Hence their peculiar adaptations to secure nitrogenous food from the insect world.

In some insectivorous plants (*see the coloured plate*) the leaves are modified into PITCHERS, hence these plants are called pitcher plants. In *Nepenthes*, an American climber, the petiole is very long and acts like a tendril at its lower part while the upper part forms the hollow pitcher, as shown in fig. 329. The lamina of the leaf is extremely reduced and forms only a small scale-like lid arching over the pitcher. The pitcher is attractively coloured and the rim is smeared with a sweet and fragrant honey. The inside of the pitcher is very smooth, so that insects trying to descend from the rim where they first land slip down and are drowned in the liquid contained in the pitcher. This liquid is secreted by small glands lining the cavity of the pitcher, and is an acid fluid containing digestive ferments. Insects falling into this liquid are killed and become gradually digested by it; the liquid is then absorbed by the plant to supply it with nitrogenous food.

Other pitcher plants, the *Sarracenias* and *Darlingtonias*, form their pitchers in rosettes on the ground. The pitchers, or **ascidia** as they are also called, are here too inflated and hollowed petioles with the lamina reduced to a small lid at the top.

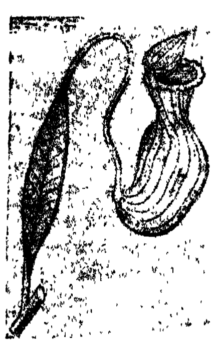


Fig. 329. *Nepenthes* —a pitcher plant; P, the pitcher l, the lamina.

Other insectivorous plants have leaves which can actually catch small insects. These are called **flytraps**. In the **Venus' flytrap** (Dionea) the leaves are spread flat on the ground with the petioles forming a pretty attractive velvety cushion. The lamina consists of two lobes on the two sides of a midrib, each lobe having a ciliated margin. There are a few sensitive bristles on the surface which when touched by an insect instantly causes the two lobes to fold up and the marginal teeth become then firmly interlocked. In this way an insect becomes imprisoned, and gradually strangled and

crushed to death. By this time a liquid is secreted which dissolves the dead body with the help of ferments, and the juice thus formed is absorbed by the plant. The leaf then opens ready for the next insect to be similarly trapped.

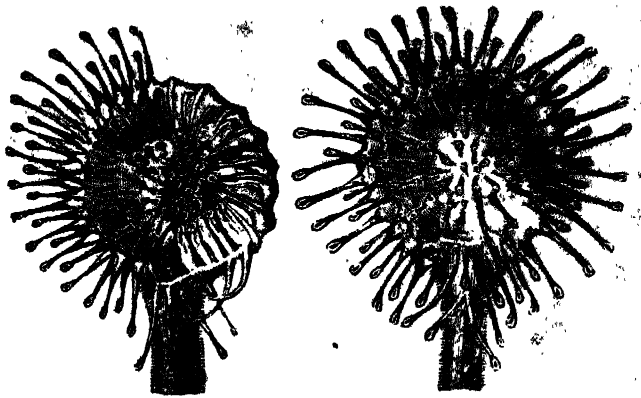


Fig. 330. Leaf of *Drosera* with the tentacles folded on an insect.
Fig. 331. The same with the tentacles outspread.

Another fly-trap, common in certain marshes of Bengal, is the Sundew (*Drosera*). The lamina here is roundish and bears a large number of delicate wine-red filaments ending in a glistening head. Small creatures are allured by the sparkling honey drops, at the top of the filaments which shine like dew drops but as soon as they alight they are held fast by the sticky secretion, and can not escape as the filaments bend towards it from all directions. The more the insect struggles the more these *tentacles* (as the filaments are called) curl over its body and secrete at the same time a copious fluid which chokes up the creature, kills it, and then gradually dissolves its body. After a time the nutritive fluid is absorbed by the plant and the tentacles again open out laying the trap for the next insect.

In another insectivorous plant, called *Pinguicula*, (see plate), the leaf becomes slowly rolled up from one margin to another when insects crawl on its surface.

In *Utricularias*, a family of floating plants found in the marshes of Bengal, some of the leaves are transformed into small bladders with a small opening at one side. Small water-mites and slugs seek shelter inside the bladder, but once within it they can not come out. Thus

entrapped they die and then their body is dissolved by an acid secretion of glands lining the interior of the bladder.

Nutrition in Saprophytes and parasites.—The Fungi as a class are either saprophytes or parasites; their special mode of nutrition will be described in the section on Fungi. Saprophytic phanerogams are rather rare. On the contrary there are many flowering plants which live parasitically upon other plants. The Alkooshy or Swarna-lata (*cuscuta*) mentioned on p. 26 is a case in point. This plant is a *total parasite*; it has no leaves and little chlorophyll and consists of repeatedly branched yellow wire-like stems. It does not assimilate carbon or nitrogen but gets organic food matters from the host plant. The seed contains a tiny thread-like embryo. On germination a short root is sent to the ground and the shoot elongates rapidly and at the same time makes sweeping movements in the air in order to catch hold of supports. If it meets with a suitable soft-cortexed plant, the stem goes on coiling round it. Short whitish protuberances now appear from the stem which penetrate the tissues of the host plant. These are haustoria (p. 26), the peculiar adventitious roots of the plant. The primary root by this time rots away and the plant is separated from the ground. The haustoria when well-developed prepare xylem and phloem tissues and these fuse with the corresponding tissues of the host. Thus the solution of raw food-matter absorbed by the host from the soil travels through the xylem of the parasite. Similarly its phloem taps the assimilated organic substances prepared by the host and conducted by phloem. The parasite really robs the host plant of its food and may eventually kill it.

Another common parasite is the *Orobanche*—a flesh-coloured plant often detected on cultivated grounds amongst various cultivated plants. It is a *root parasite*, that is, it grows with its roots attached to the roots of other plants—Brinjal, Sugar-cane, Kush-kush etc. It has no green leaves and no chlorophyll and hence depends entirely upon the host plant for the supply of assimilated food.

CHAPTER XXIV.

RESPIRATION.

Like animals plants also must breathe in order to live. They take in oxygen from the air and give out carbon dioxide (CO_2) and a small quantity of water-vapour. This process is called **respiration**. It can be shown by placing a small plant or a few seedlings in a tumbler which is then kept with its mouth covered in a dark place for twenty-four hours. A lighted taper is then introduced when it is instantly extinguished. A quantity of lime-water is also poured when it turns turbid and milky. These tests show that there is no oxygen now in the air of the tumbler but instead a large quantity of carbon dioxide. The fact that water-vapour is also exhaled by plants cannot be shown so readily, but in favourable cases the tumbler in the experiment will appear dimmed with moisture. The dimness arises from the condensation of the water-vapour given out by the plant on the sides of the tumbler.

Fig. 332 shows an apparatus for demonstrating respiration. F is a flask with a long neck the open mouth of which dips in mercury contained in a trough. The flask is partly filled with capitulas of Sunflower (or with flowers which do not wither readily, or with germinating seedlings), and a plug of cotton (C) is pushed into the neck so that the flowers do not fall when the flask is inverted as shown. A little strong solution of caustic potash is then introduced into the inverted flask standing over the mercury. A similar apparatus is fitted but without the potash. Both are then set apart for several hours or days. After some six or seven hours it will be noticed that mercury rises in the neck of the first flask. It goes on rising for some time,

for the next twenty-four to forty-eight hours, after which the mercury column remains stationary. In the second flask there is apparently no change. The explanation is that the flowers take up oxygen from the air inside the flask and give out carbon dioxide; the latter being rapidly absorbed by the potash the mercury rises (W), but it cannot rise above a certain limit. For, the volume of the mercury column indicates the volume of carbon dioxide evolved by the flowers, and this can be never more than one-fifth the whole volume of air contained in the flask. One-fifth the volume of air is oxygen, the rest is mainly nitrogen, and so the experiment shows that the *volume of carbon dioxide exhaled is equal to the volume of oxygen absorbed.* This is corroborated by the second flask the volume of air within which remains unaltered. Here potash is not used and hence the carbon dioxide evolved is not absorbed. If now a quantity of potash be introduced into it the mercury rapidly rises and comes to the same level as in the first flask.

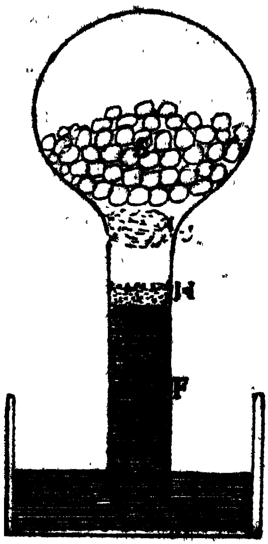


Fig. 332. Apparatus to show respiration in plants.

That **oxygen is absolutely necessary** for the life of a plant may be shown by placing small plants in large bottles the air of which is replaced by various gases—carbon dioxide, hydrogen, nitrogen and so on (fig. 333). The plants rapidly wither and die.

In an atmosphere devoid of oxygen all vital activities stop, the various movements of flowers, leaves, stomata,

etc. cease, growth does not take place, and the plant dies of sheer exhaustion. If oxygen be admitted before it is too late the interrupted vital functions are revived and the plant again looks healthy.

Fig. 333. Apparatus to show that plants can not live in an atmosphere devoid of oxygen. Different gases can be passed through the U tube into the bell-jar which stands on a glass vessel containing water.

It will be noted that respiration involves an evolution of carbon dioxide and absorption of oxygen—processes diametrically opposed to what takes place in assimilation. Only green parts of plants evolve oxygen and absorb carbon dioxide from the air (photo-synthesis) only so long as there is light. But *all living parts of plants take in oxygen from the air and give out carbon dioxide* (respiration) *both by day and night*. Hence it is not easy to show that green parts of plants are respiring during day time, for the process of assimilation takes place far more rapidly than respiration; in light assimilation masks respiration completely. If kept in the dark, however, even green parts of plants may be shown to be continuously respiring. If in the previous experiment (fig. 332) green leaves be taken instead of flowers and the apparatus exposed to light the ascent of mercury will not take place at all, for respiration is counterbalanced by the assimilation of the carbon dioxide that is given out. Thus, while light and chlorophyll are conditions absolutely necessary for assimilation,

Conditions affecting respiration are :—(1) *Oxygen*—this is absolutely necessary for no plant can live if long deprived of oxygen. (2) *Heat*—respiration is greater the higher the temperature. (3) *Only living and active parts*

of plants respire. Seeds and spores being dormant for some time after they are formed do not respire until they germinate. (4) *Rapidly growing parts respire vigorously.* Seedlings if kept in darkness respire strongly and become abnormally elongated. Any condition tending to retard growth also retards respiration. (5) *Respiration takes place in light as well as in darkness.*

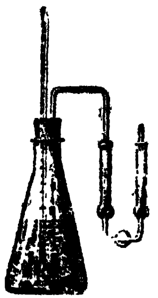


Fig. 334. Apparatus to show evolution of heat in respiration.

Heat is evolved in respiration.—This can be shown by arranging an apparatus like that shown in fig. 334. A number of germinating seedlings with a little water are taken in a bottle the mouth of which is closed with a cork provided with a thermometer and a bent glass tubing. The thermometer is pushed right into the seedlings and the glass tubing is connected with a bulbed U tube containing pumice soaked in potash solution. The seedlings take up oxygen from the air in the bottle and a stream of air is sucked into the flask owing to the carbon dioxide evolved being absorbed by the potash. The thermometer registers a temperature higher than that of the air. The same apparatus may be taken to show that the heat given out is proportional to respiration. Any thing which increases respiration, heat or oxygen, for instance, causes also a relatively higher temperature.

Oxygen absorbed for respiration is used mainly in oxidising the protoplasm and its plastic products. This oxidation being a process of slow combustion gives rise to heat and gives energy to the protoplasm to carry on its many-sided functions. It also helps to break up the many complex matters produced in plants into simpler substances which may be at once utilised for growth. It is for this reason that respiration is very active in seedlings and growing parts

of plants. Sometimes, however, carbon dioxide is expired without the absorption of oxygen. This may be observed in many seeds which germinate even in the absence of oxygen. This sort of respiration is called **intramolecular** or *anaerobic* respiration.

Assimilation and respiration form the two chief processes of **metabolism.** By metabolism is understood all the varied chemical changes which take place in the plant body. These are principally of two types: (1) *Constructive* changes which result in the construction of plastic products, and (2) *Destructive* changes whereby these products are decomposed and degenerate into waste matters. The constructive processes constitute **anabolism**; the destructive processes constitute **catabolism.** Photo-synthesis is a typical case of anabolism, respiration of catabolism. The points of distinction between these two are :—

Respiration	Photo-synthesis
[1] The simplest and most essential catabolic process—being one of *breathing*.	[1] The simplest and most essential anabolic process—being one of *feeding*.
[2] Involves absorption of oxygen and evolution of carbon dioxide and water vapour.	[2] Involves absorption of carbon dioxide and evolution of oxygen.
[3] Takes place in all living organs, in every living cell	[3] Takes place only in green organs and cells containing chloroplasts.
[4] Takes place at all times, independent of light.	[4] Takes place only in light.
[5] By it a plant loses weight.	[5] By it a plant gains in weight.

As instances of catabolic changes may be mentioned the formation of such waste matters as gums, tannins, mucilage, resins, latex and so on. The products of catabolism travel through and are stored in intercellular spaces, latex tubes, or special glands.

SUMMARY.

Assimilation is the process of building up of plant-substance from the crude food-matters absorbed from the soil and the atmosphere. Carbon assimilation or **photo-synthesis** is the chemical process whereby carbon-dioxide and water unite under the influence of sunlight to produce

carbo-hydrates, such as sugar and starch. It takes place in all green parts of plants and in presence of light. Chloroplasts are the organs for absorbing a part of solar energy and with its help they unite chemically carbon dioxide and water to form sugar or starch which is the first visible product of assimilation. After a carbo-hydrate is formed nitrogen-assimilation takes place. For this purpose carbo-hydrates are essential and also nitrates of calcium, potassium, or ammonium. The products of nitrogen-assimilation are various kinds of *albumens* which are complex nitrogenous compounds. Sulphur and phosphorous are also chemically united with the carbo-hydrates to form still more complex compounds.

The products of assimilation are dissolved by certain bodies, termed enzymes, the true nature of which is not known. An assimilated sap is thus formed in plants, and it travels in the plant through the vascular bundle-sheath and the phlœm.

During life all living organs carry on an oxidising process whereby latent energy is rendered available. This is **Respiration**. In this process oxygen from the air is taken in and carbon dioxide and water vapour are given out by plants. Though a destructive process respiration is absolutely necessary, for without it the constructive process of assimilation can not work.

QUESTIONS.

1. Describe an experiment to show that only green leaves can assimilate carbon.

2. Explain how starch is formed in leaves.

3. Give an account of the way in which plants assimilate nitrogen.

4. Give an account of assimilation in leguminous plants. What is mycorhiza?

5. What is respiration? Distinguish it from assimilation.

6. Describe an experiment to show that plants must breathe in order to live.

7. What conditions are necessary for (*a*) assimilation and (*b*) respiration and why?

8. Write what you know about insectivorous plants.

9. Explain the terms :—Metabolism, symbiosis, intra-molecular respiration, photo-synthesis, enzymes, and anabolism.

CHAPTER XXV.

GROWTH.

Growth does not mean a mere increase in volume. A dried and shrivelled grape or raisin or a date will swell up in water, but that does not indicate growth. Growth means a *permanent change in the form* of a plant, and can take place only in living parts. This change is generally seen to be an increase in volume, but there may also be no increase at all, and an actual loss in weight may occur due to respiration and transpiration.

Conditions essential to growth are :—(1) *Water*—All growing cells and organs require water, for (*a*) it makes the cells turgid, (*b*) it is a constituent of protoplasm and the plastic matters, (*c*) it is the medium of chemical changes, and (*d*) it serves to conduct the various food-matters required by the growing organ.

2. *Temperature*, which must not be either too high or too low. It exerts an important influence on absorption, photo-synthesis, rate of digestion, respiration, and so on.

3. *Oxygen*, which is necessary for respiration. It is well-known that growing organs respire vigorously.

4. *Plastic* or *nutritive materials* which are necessary for the building of new cells and protoplasm, and for increasing the materials of existing cells.

Regions of growth—Young growing organs, such as growing stems and roots, exhibit two more or less distinct zones. In one the cells divide actively, but grow little; in the other cell-division is greatly diminished or altogether lacking, and the increase in size of the cells pronounced. The former consists almost wholly of meristem and may be called the ***zone of division***, while the latter consists of cells

more or less modified into parenchyma and may be termed the *zone of elongation*. The zone of division is far shorter than that of elongation; it occupies the tip of the growing organ, and the zone of elongation extends back from it for a distance several times greater. Elongation is greatest just below the meristem and it decreases gradually towards the permanent adult tissues of the organ (see pp. 205—7). The region of growth in the stem is as a rule much longer than that of the root, while in several twiners it may extend over several feet in length!

The **rate of growth** of an organ (of every cell of a plant) varies gradually throughout its course. It begins slowly, increases to a maximum, and then becomes slower till it stops. The time during which these regular changes in the rate can be observed is generally spoken of as the *grand period of growth*. At the very apex of an organ the cells are merely dividing, growth consists mainly in an increase of the quantity of protoplasm and cells; as new cells are continually formed from the meristem those which are farthest from the apex cease to divide and a different process of growth takes place in them. This is growth in volume or extension. Lower down the cells gradually pass over into a state of decreasing growth and ultimately into the condition of permanent tissue.

External factors exert a powerful influence on growth; all elongating organs are highly sensitive and they modify growth in response to the influence exerted by the particular soil and climate in which the plant is growing. Growth in the sense of elongation is greater when the external conditions are moderate; this is the *optimum* state, as opposed to the *maximum* and *minimum* states.

1. **Light**, though one of the prime factors for assimilation, definitely retards growth. A plant kept in darkness elongates more rapidly than when it is in light. Plants

which live in sunny localities are of a dwarfed appearance while those which live in shade, such as climbers, have usually long internodes. *Intense light causes a cessation of growth*, and in proportion as its intensity diminishes elongation of organs, especially of the stem, is favoured. It is for this that plants growing in hot places, where for instance the tropical sun is directly overhead, are short, stiff and woody, and shade plants are soft, lank, delicate, elongated and have soft-textured leaves. Long-continued darkness, however, acts injuriously on plants; they fail to assimilate but elongate abnormally, turn yellow and then die. This happens because a moderate intensity of light is required to stimulate the protoplasm to carry on growth-processes; failing this it is broken down or disorganised by continuous respiration. An exposure to light, if darkness has not prevailed too long, is often sufficient to revive a dying plant.

Light also determines the *direction of growing organ*. If a small Sunflower or any common pot plant be kept before the open window of a partially darkened room it will be observed that within a few hours the stem bends towards the window. If a sprouting Onion be left suspended by a thread before the window of such a room for a day or two, or long enough for the formation of a few roots and the green shoot, it will be noticed that the green shoot is bent towards light while the white roots point away from the window. This shows that the direction of a growing organ is regulated by the direction of the incident light. Several small plants, Kachoo (*Colocasia*) for instance, commonly growing near the the margins of ponds and marshes, turn their leaves towards the east in the forenoon and gradually bend westwards on the approach of dusk. This movement obviously takes place to catch the direct rays of the sun. This phenomenon is known as heliotropism. The shoot always moves towards

the source of light, it seeks light and hence is said to be *positively heliotropic*. The root always moves away from light, it is *negatively heliotropic*. It is for this that roots of some climbers and epiphytes seek the crevices in the bark of the supporting tree. Often leaves and branches move in such a way that light falls perpendicularly on them; they are *transversely heliotropic*. This transverse heliotropism may be witnessed most conspicuously in plants which trail or spread on the ground, such as the Amrool-shak (*Oxalis*), or in rhizomes. The leaves turn and twist the petioles variously and always secure a position in which their lamina is spread almost horizontally to catch the direct rays of the sun.

Growth is influenced only by a part of the solar rays. Of the seven coloured rays which constitute solar light, the red to yellow half only is of importance in assimilation. Exactly the other half, namely the blue and violet portion, is concerned in growth. This can be shown by the experiments with the double-walled bell-jars described on page 296. Two seedlings of Sunflower or Pea, say, are placed separately under two jars which are left before the open window of a partially darkened room. The jars are filled one with the red bichromate and the other with the blue ammoniacal copper oxide solution. In a short time it will be noticed that the seedling under the blue jar has bent towards the window while that in the other jar has not appreciably changed its position. If kept long the seedling in red light will show abnormal elongation and etiolation, that under the blue jar grows but little. This shows that normal growth and movement can take place only in blue and violet coloured light. If kept longer and the necessary conditions for nutrition be fulfilled (excepting of course light) both plants die; one for want of assimilation and hence from sheer exhaustion (blue light): the other (red light) for want of that moderate stimulation

by light without which growth cannot go on. The plant under red light grows as if in darkness.

2. **Moisture** also directs growth. Thus roots always move towards moisture. This phenomenon is called **hydrotropism.** The root is said to be *positively hydrotropic,* while the stem is *negatively hydrotropic,* because it moves away from moisture, towards air and light. Presence of moisture in the soil greatly determines the form of the root. Plants growing in marshy places have seldom any long tap-root, for their stems copiously produce thin fibrous roots. Desert plants, however, have to seek water from a great depth ; their roots elongate by virtue of their hydrotropism, ultimately reach the sub-soil water, and hence are abnormally long and stout (p. 19).

3. Like light and moisture, **gravity** also is an important factor in determining the direction of growth of an organ. Gravity no doubt pulls all things equally, but it *stimulates growth* differently in different organs of plants. The phenomenon of the growing organ moving under the influence of gravity is known as **geotropism.** The main root always grows downwards, and hence is said to be *positively geotropic.* The main stem always moves away from the earth, and is hence *negatively geotropic* ; rhizomes and branch-shoots are *transversely geotropic,* they place themselves at right-angles to the lines of action of gravity.

4. The **temperature** of the medium in which an organ is growing also influences its growth. No growth is possible at the temperature of ice, nor at that of boiling water. A moderate temperature is essential for growth, but within certain limits growth is greatly accelerated by heat or warmth.

The above are the most important factors which universally affect plants. Others of less importance are : the nature of the climate, and the salinity, porosity, richness or poverty of the soil of the locality in which a plant is living. These also operate on the growth of plants and give rise to what are called **growth-forms.** (See Ecology.)

CHAPTER XXVI.

REPRODUCTION.

Reproduction means the production of new plants out of a mature parent. A plant cannot grow indefinitely; it has a definite period of growth, a definite term of life, so to say. But normally all plants reproduce themselves before they die. There are various methods by which plants are reproduced; these are of three principle types; (1) *Vegetative reproduction*, (2) *Sexual reproduction* and (3) *Asexual reproduction.*

In **vegetative reproduction** parts of a plant, specially developed for the process, separate from the parent plant and develop into new plants.

In **sexual reproduction**, a more complicated process, two kinds of reproductive cells are first formed, neither of which is capable of further development, and both may perish unless opportunities are given for their fusion with each other. The reproductive sexual cells are called *gametes.*

In **Asexual reproduction** single cells, called spores, are separated from the plant, and these develop into new plants. It is not known in higher plants but is common in the Cryptogams where these spores are formed in very large numbers.

Vegetative reproduction in higher plants consists merely in the separation of lateral shoots or special buds, or in the division of a single plant into several. Thus aquatics and herbaceous plants multiply very rapidly by producing stolons, offsets, runners or rhizomes, corms, bulbs, and tubers. The parent plant producing these special forms of shoots dies after a time, and a crop of new plants is then formed which separate from one another by the rotting

away of the connecting branches. The different forms of underground shoots (see pp. 32 to 34) contain large stores of food matter at the expense of which the superficial "eyes" or buds sprout up into new plants. For suckers, stolons, runners and offsets see pp. 35 to 37.

Aerial buds and tubers are also formed in certain higher plants, which separate from the parent and sprout up like seeds. The adventitious buds in the leaf-margin of Bryophyllum (p. 43, fig. 62) are instances. In certain Lilies small bulbs are formed in the axil of the bract-leaves; these are especially constructed with a view to detachment from the parent plant, and are called bulbils. An instance is *Globba bulbifera*, a creeping herb which produces small bulbils in the axils of lower bracts of the inflorescence. When the plant dies the bulbils remain on the ground and give rise to new plants. The Kham-aloo (fig. 47) produces little tubers on their climbing stem which separate from the plant and falling on the ground produce new plants.

Special multiplying shoots, such as stolons, etc., are not formed in larger shrubs and trees, but it is well known how simple it is to increase and multiply a plant by *cuttings* or *graftings*. The common fruit trees, Mango, Litchi, etc., are thus propagated by gardeners; also the Rose, the Marigold, and other flower-plants. Some plants, such as the Sajina, are very readily increased by cuttings; all that is necessary is to lop off a branch and plant it.

Sexual reproduction in its simplest form consists essentially of a fusion of two protoplasm masses or naked cells called *gametes*. The gametes unite to form a *zygote*, which is a single cell from which by repeated cell-division a new generation arises. In the lower plants the gametes are very simple in structure, but are often distinguishable as (1) a large female cell or ovum, consisting of a nucleus and large cytoplasm, and (2) a small motile cell or spermatozoid,

consisting of a large nucleus and thin cytoplasm with cilia (see p. 167). The process of sexual union is called *fertilisation*. Both the sexual cells are naked; they have no cell-wall. In the higher plants (Phanerogams) the male cells are not motile because they are not ciliated. The process of sexual reproduction differs in the different classes of plants and will be described under them. The following account refers only to higher plants, Dicots and Monocots generally.

Fertilisation in Angiosperms (Dicots and Monocots) takes place after pollination. The pollen-grain germinates on a suitable stigma; the extine is either burst or perforated and the intine bulges out in the form of a short tube (fig. 215) which grows into the tissue of the stigma feeding on the juices it contains. The tube grows down through the tissue or canal of the style into the cavity of the ovary. When it reaches this it is attracted to the micropyle of an ovule. It then passes through passage (micropylar) and pierces the tissue of the ovule until it reaches the embryo-sac (p. 119, fig. 214).

The embryo-sac is a single cell of the ovule. By the time the pollen-tube reaches the ovule, the embryo-sac is fully developed. At first it swells and its nucleus divides successively into eight daughter nuclei. Three of these move towards the upper or micropylar end of the embryo-sac and three towards the lower end, while the remaining two, called *polar nuclei*, move towards one another in the middle of the embryo-sac and fuse to form the *secondary nucleus* of the embryo-sac. The three nuclei at the micropylar end collect protoplasm about them and so form three naked cells. They constitute the *egg-apparatus*; two of them are similar and are termed the *synergidæ*, while the third which lies between them is the *egg-cell* or ovum. This is the female sexual cell (*Ooplasm*) or gamete which is destined to be fertilised by the male sexual cell of the pollen-tube. The

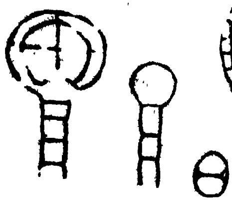
three nuclei at the lower end of the embryo-sac themselves are called the *antipodal cells*. The egg-apparatus is concerned in fertilisation. The antipodal cells have no further use.

In the pollen-tube there is a large nucleus or naked cell distinct from the nucleus of the pollen-tube itself. This is embedded in the frothy protoplasm of the pollen-tube and sooner or later divides into two *generative nuclei* or male sexual cells (*spermatoplasm*) which are carried into the embryo-sac by the pollen-tube. At the moment the pollen-tube approaches the embryo-sac, the synergidae cells either dissolve or secrete a substance which guides the generative nuclei to their destination. Then the pollen-tube reaches the embryo-sac, its tip bursts and the contents escape into the embryo-sac. One of the two generative nuclei fuses with the nucleus of the ovum, while the other fuses with the large secondary nucleus of the embryo-sac. From the fertilised ovum, which soon after surrounds itself by a cell-wall and then repeatedly divides, arises the multicellular embryo, and the nucleus formed by the union of the secondary nucleus and one of the generative nuclei of the pollen-tube constitutes the *endosperm nucleus* which later on produces the endosperm. The embryo-sac is then rapidly enlarged. The endosperm nucleus then rapidly divides into a large number of nuclei lying in the protoplasm lining the wall of the embryo-sac. Cell-walls are then formed around these nuclei and thus a multicellular tissue called *endosperm* arises. This peculiar form of cell-formation must be contrasted with that given on p. 204, and is known as *free nuclear division*. The cells of the endosperm become gradually filled with reserve food matter which nourishes the embryo (p. 154). Within the embryo-sac, then, we get two tissues developed: (1) the embryo, and (2) the endosperm. The endosperm cells become gradually filled with food-matter and it often grow at the expense of the tissues of the

nucellus. The cells of the nucellus outside the embryo-sac, too, become filled with food-matter and constitute the perisperm (see p. 153).

The fertilised ovum first secretes a cell-wall and then begins to divide. At first a row of cells, called the *pro-embryo*, is produced (fig. 335,2); the end-cell of this swells up and then divides, not in a row, but on all sides, so that a globular mass of cells is formed (fig. 335,3). From this by repeated cell-division the embryo is formed; the rest of the pro-embryo forms the *suspensor* which sinks in the endosperm tissue and sucks up nourishment from it. In Dicots two cotyledons are formed at the end of the growing embryo (fig. 336), and the growing point of the shoot originates at the base of the depression between them. In Monocots there is a single large cotyledon, while the growing point is situated laterally at the base of the cotyledon.

Fig. 335.



(3) (2) (1)

Fig. 336.

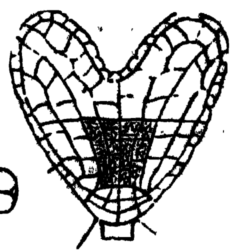


Fig. 353, 1, 2, 3, shows the gradual development of the suspensor and embryo from the fertilised ovum. Fig. 336, the embryo developing two cotyledons.

(*For Fertilisation in Gymnosperms, and Cryptogams See Chapters XXXI to XXXIII*).

CHAPTER XXVII.

MOVEMENTS OF PLANTS.

Kinds of movements—It has been already said that the protoplasm is highly irritable and so also are all young growing parts. This irritability is manifested in plant-organs in the form of movements. These are mostly changes in position; an actual bodily transport or locomotion, as in animals, is obviously impossible in plants. The various movements in plants are typically of two kinds: (1) **spontaneous** or **autonomous** movements which take place automatically and are due to internal causes not clearly understood, and (2) **paratonic** or **induced** movements brought about by the application of external stimuli, such as heat and light, moisture, contact with solid bodies and so on. A certain class of movements, known as **variation** movements, takes place in mature organs where an alternation in the turgidity of the cell acts as the immediate cause. The spontaneous and paratonic movements are generally connected with growth and hence they take place mainly in the young growing parts of plants.

Spontaneous movements.—These movements are very clearly observed in all young growing seedlings, in growing tendrils, in young leaves, and during the development and opening of flowers. The elongation of the axis of a seedling never takes place in a straight line. At first one side and then another of the growing point of a shoot or root grows more rapidly than the rest and thus curvaturres take place successively on all sides. Consequently the growing tip is pushed not in a straight line but advances in such a way as to describe regular or interrupted circles or spirals in

space; it lies, for instance, at one time towards the north, at another towards the east, then successively to the south and west till it reaches its former direction *i. e.*, the north, and again repeats the cycle of movements. The advancing apex thus describes a helix or a spiral line in space. This movement is called **circumnutation** and is one of a class of more extensive movements, called **nutation** movements, in which the growing organ curves first over one side and then over another. A simple case of nutation is the bending of the flower-stalks of the Onion. The young flower-stalk at first remains bent on one side but straightens itself gradually till it becomes quite erect, and then again bends over to the opposite side. Such nutation curvatures take place because first one side and then just the opposite side of the stalk grows more vigorously than the other. Circumnutation, or revolving nutation as it is also called, is also very marked in tendrils. In certain plants of the Cucumber family the rotatory movement of the young tendrils is so very rapid that it may be followed even with the eye if closely watched for some five or ten minutes.

Nutation movements in leaves and flowers takes place in a special way. During the early stages of growth the leaf remains folded or rolled because the lower surface grows more vigorously than the upper—this condition is known as *hyponasty*. After some period the upper surface grows more rapidly and consequently the young leaf is now fully opened and spread flat this movement is known as *epinasty*.

The above are instances of autonomous growth movements, movements, that is to say, which take place spontaneously in growing parts of plants by virtue of certain inherent property of the growing organs. Spontaneous movements also take place in many mature parts of plants where the immediate cause is not to be sought in unequal growth, as in the last case, but in some other mechanism. For instance, in the

Ban-charal (*Hedysarum gyrans*), a small herbaceous weed, the compound leaf consists of one large central leaflet and two much smaller lateral leaflets. On a warm day these lateral leaflets execute very peculiar movements, apparent even to the naked eye, in the form of up and down strokes in quick-succession. Examined closely they are seen to make small irregular circles in space with their tips and so the movement is in the form of nutation. Such rhythmic movements are called autonomous variation movements.

Paratonic movements.—Paratonic or induced movements take place in all growing organs which being highly sensitive are always stimulated to grow in certain directions determined by external factors, such as light, heat, moisture, gravity, chemical substances, contact with a solid body and the like. Consequently, the movements which take place under the influence of such external factors are in the main *directive* movements (tropisms) or **tropic movements.** According to the nature of the stimulus the movements are called *heliotropic* (light), *thermotropic* (heat), *hydrotropic* (moisture), *geotropic* (gravity), *chemotropic* (chemicals), and *haptotropic* (contact). Tropic movements may be (1) *positive* or towards the source, (2) *negative* or away from the source, and (3) *transverse* or perpendicular to the source of the stimulus. The way in which the stimuli (external factors) act in producing movements is this. In a positive tropic movement the side nearest the exciting cause grows less vigorously than the opposite side and so this side pushes the growing point towards the source. Thus in positive heliotropism (p. 313) the illuminated side grows less than the other side. In the positive geotropism of the root (p. 315) the side nearest the earth grows less than the upper side. In a negative tropic movement exactly the reverse happens: the side nearest the source is stimulated to grow more vigorously than the other. Thus, in the negative heliotropism of main roots the illuminated side elongates comparatively more rapidly than the other; in the

negative geotropism of the shoot the lower side elongates more than the upper. Hence the curvatures. The influence of these external factors being directive is exerted only when there is unilateral or one-sided action. Light falling on one side, gravity acting from one side, moisture affecting one side, of a plant can only stimulate the growing organ so as to produce the curvatures. If a plant be kept rotating before a source of light, before a window, say, there is no heliotropic curvature. So if a plant be held horizontally and kept rotating, so that its axis remains parallel to the earth, there is neither the negative geotropic movement of the shoot, nor the positive of the root; the whole plant grows straight horizontally. This is because all sides of the rotating organ are stimulated equally; they grow equally on all sides and so no curvature is possible. It is in this respect that these paratonic movements differ from the autonomous movements. A young seedling, for instance, if rotated as above will not fail to show its circumnutation. So, too, in the case of young tendrils.

Chemotropism, or movement induced by some chemical substance, is a very extensive phenomenon occuring chiefly during sexual reproduction. The pollen-tubes of Phanerogams are always led by sugary secretions in the tissues of the style and stigma. They are attracted by the particular chemical substance, sugar, and may be made to grow towards a solution of sugar when cultured artificially. The fine threads of Fungi are also led by the decaying substances of the substratum to spread towards the decomposing organic body. The movement of the tentacles of the fly-catcher, Drosera (fig. 330, p. 303) is another instance of chemotropism. The presence of a nitrogenous food matter anywhere in the lamina induces at first a copious outflow of secretion from the tentacles and then their bending inwards.

Closely related to these tropic movements of curvature are the **tactic movements** of naked free-moving protoplasts which are directed to move towards certain objects by the influence of tropic factors. Thus, the spermatozoids, the male sexual cells of lower plants, swim through water and move towards the female sexual cell, being attracted by certain matters which it secretes. The chemical substance of the secretion diffuses through water and directs the movement. This phenomenon is called **chemotaxis** and the movement **chemotactic movement.**

Chloroplasts change their position in a cell according to the intensity and direction of light; This is called **phototactic movement.** When light is intense, the chloroplasts of the palisade cells of a leaf avoid the upper or outer walls and range themselves in parallel rows on the lateral walls of the cells, thus placing themselves not at right angles to but almost parallel with the rays of light. In weak or diffused light however they move towards the upper wall and form a green plate which can readily absorb the small amount of light now available.

Twining plants.—The young shoots of twiners show a peculiar movement by means of which they twine round upright supports. The first few internodes of a twiner grow rapidly and become very long with the leaves remaining undeveloped for a long time. The free end of the shoot bends to one side and becomes more or less horizontal. At the same time it begins to revolve in a circle, either from right to left, or in the opposite direction (see dextrorse and sinistrorse twiners, p. 38). This revolving movement is at first autonomous in character, for the growing tip nutates. Lower down, however, it is a case of *lateral geotropism* where one of the two sides, either the right or the left, not the upper or the lower, of the bent shoot grows faster than the other side under the stimulus of gravity. The horizontal portion of the shoot consequently bends constantly in one direction, either to the right or to the left, and sweeps through the air in widening circles, and as soon as an upright support is reached the twining begins. At first loose horizontal coils are

thrown about the support, but gradually the older or lower coils are straightened out more and more, so that the coils are now a steep spiral. This straightening is due to *negative geotropism*, as is the case with all stem; the upper coils grow away from the earth, and this tends to tighten the spiral and press them upon the support. The *twining* thus comes about by (1) the revolving movement of the bent apex due to lateral geotropism, and (2) the negative geotropism of the older parts of the coiled stem. After the twining is accomplished and the firm grip has been obtained the leaves begin to grow and unfold their large lamina. The delay in the development of the leaves allows a more free movement of the circling tip, for the leaves might otherwise prove an obstacle in getting a support.

The movement of tendrils in tendril-climbers is a case of paratonic movement induced by *contact stimulus*. This is called *haptotropism*. Young tendrils which have not yet come in contact with a rigid body move autonomously sweeping through the air, thus executing a movement of circumnutation (p. 321). If they do not find any solid object round which they can twine they stop their circling movement in a short time, hang loose, often form a thin spiral coil, and then wither. But if a suitable support comes in contact with the revolving tendril, the contact quickly induces an increase in growth of the opposite side of the organ, and this causes the free end to turn round the support. New portions of the tendril are thus brought in contact with the support, and the continuous rubbing with a rough object stimulates the tendril to turn more quickly and firmly round the support, a new thrill of stimulus being sent through the tendril at each coil. When the support has thus been firmly grasped, another movement takes place in that part of the tendril which lies between the plant and the support (see fig. 52), by

virtue of which the climber drags itself more towards its shelter. This part of the tendril is twisted like a cork-screw, and as it lies between two fixed points there are two opposite windings, one to the right and the other to the left, which balance each other, and between the two lies a neutral untwisted portion called the *point of reversal,* so called because at this point the spiral begins to be reversed *i.e.* to go opposite to the direction of the other half.

Young tendrils grow very rapidly while they are circumnutating; at this stage they are very thin, soft, and highly flexible being made up mostly of collenchyma. An old tendril which has already grasped a support becomes gradually thickened and hardened, for lignification goes on very fast, and an ample sclerenchyma makes it strong like a cable.

Sleep Movements.—Many foliage leaves and floral leaves (petals and sepals) assume different positions by day and by night. This is very noticeable in the foliage of the Pea family (Pea, Bean, Pulses, Tamarind, Acacia, etc) the compound pinnate leaves of which remain spread out during day time but fold up in pairs at dusk and remain folded for the night. A similar folding movement of the leaves may be seen in the Amrul-shak (Oxalis). This night or sleep-position, as it is called, is due to a change of turgor in the cells at the base of the leaflets where there is an erectile tissue known as the *pulvinus.* This sleep movement (*nyctinastic* movement), as it is called, is brought about by variations in the intensity of light or of the temperature of the air. It is not a growth movement for it takes place in the fully grown up leaves but belongs to the class of movement called *variation movements.*

Similar closing movements are seen in some flowers, such as the Water-lily and Morning-glory, and also in certain capitulas, as in *Helichrysum,* which open in daylight and close up at night. That they are due to variations of light and temperature is seen from the closing

of the flowers even during the day when the air is suddenly chilled by a cool breeze, a shower, or a dark cloud. When the cloud or chill blows over and the sun again shines, the temperature of the air is raised and the flowers open once more.

In the *sensitive plant* (*Mimosa pudica*—Lajjabaty lata fig. 147) the leaflets exhibit a remarkably rapid irritable movement. They are extremely sensitive to contact. On a sudden, though gentlest, stroke of a stick, or upon any sudden vibration of the leaf, the leaflets fold up pair after pair in rapid succession, and when all the leaflets are folded up and the leaf is apparently at rest, all at once the secondary petioles (see fig. 147) are drawn nearer and the main petiole sinks down. The same movements are performed when the leaf is disturbed in any other way. For instance a pair of leaflets may be suddenly cut off with a scissor, or a cone of light may be focussed at the base of a leaflet, or a burning stick held near it, and so on. These movements of irritation is said to be due to variation of turgor in the cells of the *pulvini* which are present at the base of each leaflet, of the secondary petioles and of the main petiole.

PART IV
SYSTEMATIC BOTANY

CHAPTER XXVIII.

CLASSIFICATION.

The most obvious classification of plants, as we have seen in the introduction, is to divide it first into the two great sub-kingdoms the FLOWERING PLANTS or the **Phanerogamia**, and the FLOWERLESS PLANTS or the **Cryptogamia**. The main distinction lies in the mode of reproduction. Flowering plants reproduce by seeds, for the main object of the flower is to produce seeds; while the flowerless plants multiply by spores. Spores are UNICELLULAR bodies formed asexually without the intervention of sexual cells, whereas seeds are MULTICELLULAR bodies containing a multicellular embryo formed sexually as a result of the union of sexual cells. Hence flowering plants or Phanerogams are also called *seed plants* or *Spermaphyta*, (fr. *Sperm* = a seed) and flowerless plants or Cryptogams are spore plants or *Sporophyta*.

The Cryptogamia consist of three broad divisions, and seven classes. The first division, **Pteridophyta** or Fern-like plants, the highest group of Cryptogams, comprises plants with roots, stems and leaves like the Phanerogams, all provided with vascular bundles. They produce spores from their leaves which are called *sporophylls*. The three classes which constitute the Pteridophytes are: (1) the Ferns with large leaves, (2) the Lycopods with small scale-like leaves, and (3) the Equisetums with minute teeth-like leaves and whorled branches. The other two divisions of Cryptogams do not possess true roots, stems and leaves, nor have they any vascular tissue; their spores are not produced from leaves, so that sporophylls are not present,

but the spores arise in certain chambers. The **Bryophyta** are Cryptogams with the spore-sac stalked and opening by a lid. They are more complex in structure than the other group called the **Thallophyta**, the lowest and simplest of the Cryptogams. The Bryophyta comprise two classes: (1) MOSSES with an axis like a stem and simple leaf-like plate of cells, and (2) the LIVER-WORTS which have typically a thallus.

The structure of Bryophytes and Thallophytes is very simple; they are made up of simple cells, and are hence called CELLULAR PLANTS, as opposed to the Pteridophytes and the Phanerogams which are VASCULAR PLANTS; so called because they contain also vascular tissues. The body of the plant in the first group is a simple thallus consisting of a plate or chain of simple cells. Only in the higher Bryophytes, *e.g.* the Mosses, are leaves and stems formed, but these, too, are made up of simple cells, the various tissues such as sclerenchyma, tracheides, sieve-tube, etc, which characterise the leaves and stems of vascular plants, are totally wanting. In some of the lower thallophytes the plant consists of a single microscopic cell or a group of cells.

The difference between the **Algae** and the **Fungi**, the two classes which make up the thallophyta, lies in their mode of living and nutrition. Algae have chloroplasts in their cells and so can prepare their own food like ordinary plants. They are usually green though some of the sea-algae are coloured by the presence of some pigments which mask the green colour of chlorophyll. Fungi do not possess chloroplasts; hence they cannot prepare their own food like green plants from the inorganic constituents of the earth. They are white or sometimes coloured by the presence of a coloured cell-sap. Algae are autophytes (p. 300). Fungi are saprophytes or parasites (p. 304); they are

regarded as degenerate forms of Algae which have been compelled to adopt a parasitic or saprophytic mode of life. Almost all Algae are aquatics; many Fungi are also aquatics, growing on decomposing leaves, etc, but the majority of Fungi are non-aquatics, growing everywhere on rotten or fresh plant or animal body. They are all multiplied very extensively by spores formed in simple chambers called *sporangia* which are far simpler in structure than the spore-sac or capsule of Bryophytes. The spores are scattered broad-cast by the wind. Some of the aquatic thallophytes produce spores which are not scattered by the wind but swim freely in the water and thus themselves wander away. These spores are called *swarmspores.* They are naked protoplasts, without a cell-wall, and are provided with a tail or cilia (p. 167) by means of which they move about in water like tadpoles.

The Phanerogamia consist of two divisions: the **Angiospermia** or plants with a seed-case (ovary) and the **Gymnospermia** or plants with naked seeds without a seed-case. The carpel in the first forms a closed sac or ovary, in the latter it does not form a chamber, but is a flat scale-like leaf from which the ovules arise. Both are seed-plants, but flowers, as ordinarily understood, are not formed in Gymnosperms: they have no sepals and petals, and no fruit or pericarp. As there is no ovary, style, and stigma, the pollen-grains germinate directly on the ovule at the micropyle, and not on the stigma as in Angiosperms. The Pines are Gymnosperms. The Angiosperms comprise the two great classes, the Monocots and Dicots. The difference between these two, in every particular point, has been described in the first and second parts of this book and may now be summarised as follows:—

DICOT.	MONOCOT.
ROOTS are usually much-branched tap roots but may also be adventitious.	**ROOTS** are normally adventitious, the primary root not persisting.
STEMS are usually much-branched, produce axillary as well as terminal buds copiously.	**STEM** is not much-branched, grows mainly by the terminal bud.
LEAVES are small, with reticulate venation.	**LEAVES** are large with a sheathing base and parallel venation.
FLOWERS are as a rule pentamerous or tetramerous, rarely trimerous or dimerous.	**FLOWERS** are as a rule trimerous, though often much reduced.
PERIANTH when present is usually hetero-chlamydeous, having distinct calyx and corolla.	**PERIANTH** when present and prominent is homochlamydeous.
EMBRYO has two cotyledons, lies inside an albuminous or exalbuminous seed.	**EMBRYO** has one cotyledon and often lies in a copious albumen.

The Dicots and Monocots are very large classes and so they have been divided into smaller sub-classes as shown in the table below :—

Classification of Angiospermia.

CLASS I. **Dicotyledons,**—plants with two cotyledons.—

Calyx and Corolla both present—

SUB-CLASS I. petals free, stamens definite or indefinite ... ... **Polypetalae.**

Series 1. Fls. hypogynous, sepals free ... **Thalamiflorae.**

Series 2. Fls. peri-or epigynous, sepals united ... ... **Calyciflorae.**

SUB-CLASS 2. Petals united, stamens definite ... **Corolliflorae.**

Calyx present, corolla absent—

SUB-CLASS 3. Corolla always, calyx often, absent, fls. reduced, often 1-sexual.......... Apetalæ or **Incompletae.**

CLASS II. **Monocotyledons**—plants with one cotyledon—

SUB-CLASS I. Fls. conspicuous with coloured perianth ... ... **Petaloideae.**

SUB-CLASS 2. Fls. minute, naked, on a spadix ... **Spadiciflorae.**

SUB-CLASS 3. Fls glumaceous, scaly, in spikes ... **Glumiflorae.**

The following scheme gives a tabular classification of

The Vegetable Kingdom.

1st. Division.	**Angiospermia**		I. Sub-kingdom **Phanerogamia** or Flowering plants also called **Spermaphyta** or seed-plants.
Class I.	**Dicotyledons.**		
Sub-Class 1.	Polypetalæ.		
„ 2.	Gamopetalæ.		
„ 3.	Incompletæ.		
Class 2.	**Monocotyledons.**		
Sub-Class 1.	Glumifloræ.		
„ 2.	Spadicifloræ.		
„ 3.	Petaloideæ.		
2nd. Division.	**Gymnospermia**		II. Sub kingdom **Cryptogamia** or Flowerless plants, also called **Sporophyta** or Spore-plants.
Class 3.	**Gymnosperms**		
3rd. Division.	**Pteridophyta**		
Class 4	**Ferns.**		
Class 5.	**Lycopods**		
Class 6.	**Equisetums.**		
4th. Division.	**Bryophyta**		
Class 7.	**Mosses.**		
Class 8.	**Liverworts.**		
5th. Division.	**Thallophyta**		
Class 9.	**Algae.**		
Class 10	**Fungi.**		

The Phanerogamia, especially the Dicots and Monocots, comprise a wide range of plants which are grouped into families called **Natural orders** and into smaller groups called **Genera**. Individual plants which are quite alike in all important particulars form a **Species**. Thus the hundreds of seeds which a Pea plant produces all give rise to the Pea. For all practical purposes the plants are identical and resemble their parent, though slight differences, such as size of the plant, number of pods, etc., may be traced. But in the general characters of every organ, stem, leaf, flower, fruit, seed, etc., they perfectly agree, i.e., they are of the same species. Hence species may be defined to be a group of indivi-

duals which possess in common all the important characters of their vegetative and reproductive organs, so that they may be regarded as being descended from a common ancestor. There may be slight differences in the members of a species, just as there are differences between one man and another of the human species, but in all essential respects they are quite alike. A **genus** (*plural* Genera) is an assemblage of allied species. Those species which resemble strikingly, especially in their floral structure, must be very nearly allied and hence they are placed under a group called genus. Thus the Gourd is a species; its seeds all produce the same plant, the Gourd plant. The Pumpkin is another species; its seeds, too, produce nothing but the Pumpkin. But both have the same kind of floral structure. Hence they constitute a genus; they are two distinct species of the same genus. *Genera are groups of species which have the same floral structure.* In naming a plant the name of the genus is placed first and then that of the species. Thus the Gourd is called *Cucurbita maxima* and the Pumpkin *Cucurbita pepo.* Similarly the melon and the Cucumber are distinct species of the same genus *Cucumis*; the Melon is called *Cucumis Melo,* and the Cucumber is *Cucumis sativus.* The Gourd and the Pumpkin both have large gamopetalous bell-shaped flowers; they belong to the same genus *Cucurbita.* The Melon and the Cucumber, however, have a different form of flower; it is rather small and only slightly gamopetalous, rotate, and has 5 large petal-lobes. Hence these plants constitute a different genus *Cucumis.* But obviously all the four plants are related. They are all tendril-climbers, have unisexual flowers, 3 stamens with long folded anthers, inferior ovary with 3 parietal placentas, and succulent fruits. Each of these characters may not be of any value separately but together they give a clear indication of a family resemblance between

the plants. Hence they are said to form a family or Natural order called the Cucumber family or the *Cucurbitaceæ.* A Natural order is simply an assemblage of allied genera, just as a genus is an assemblage of different species. The sub-classes mentioned above are composed of numerous Natural orders.

Sometimes a single striking character determines a Natural order. Thus, the Natural order Leguminoseæ includes a very large number of plants which are distinguished by their fruit which is either a legume or a loment. The order includes the Pea, Bean, all the Pulses, and even such large trees as the Tamarind, Sisso, Sirish and Asoka.

Sometimes some new, more or less constant, characters are found amongst several individuals of a species giving rise to varieties of that species. Thus, the Rice plant forms a species, but there are various varieties, such as Aman, Aush, etc. Similarly, the Cabbage and the Cauliflower are cultivated varieties of the same species *Brassica oleracea.* Varieties spring especially from artificial selective cultivation followed extensively by gardeners for producing new and better kinds of flowers and fruits. Thus there are several varieties of the Banana, Potato, Citron, etc.

In the following table some of the more important Natural orders are given with their distinguishing characters.—

1. Thalamiflorae—thalamus conical or short, flowers hypogynous, petals free, sepals generally free, rarely united, stamens indefinite.

Ovary apocarpous, carpels free.

Flowers acyclic, petals many, aquatic herbs with floating leaves, Lotus family ... ... **Nymphaeaceae.**

Flowers trimerous, sepals 3, petals 3 or 6, valvate, trees or shrubs—Custard Apple family ... ... **Anonaceae.**

Flowers trimerous, sepals 3, petaloid, petals in 2 or more whorls of 3 each, imbricate, trees or shrubs, sometimes climbing—Magnolia family ... ... **Magnoliaceae.**

Ovary syncarpous, 1 or more celled.

Ovary 1-celled, placentas parietal, fruit capsule,

Flower cruciform, sepals 4, petals 4, stamens 6, tetradynamous, fruit a siliqua or silicula, carpels 2—Mustard family ... ... **Cruciferae.**

Flower rosaceous, sepals 2, petals 4, stamens many, carpels many, placentas protruding into the I-celled ovary.
Poppy family ... ... **Papaveraceae.**

Ovary syncarpous, 4 or 5 celled, placenta axile.

Flower not symmetrical, calyx imbricate, seed arillate, stamens 5-10, free,—Litchi family ... ... **Sapindaceae.**

Flower symmetrical, calyx valvate,

Stamens many, monadelphous, Anther I-celled, fls. 2-sexual, Cotton family ... ... **Malvaceae.**

Stamens 4 or 5, free, opposite petals, petals small, Jujube family ... ... **Rhamnaceae.**

2. **Calyciflorae**—sepals united, petals free, flowers peri- or epigynous, thalamus flat like a disc or hollow like a cup.

Ovary superior, flower perigynous, regular or irregular.

Ovary apocarpous, of one or more free carpels,—

Carpel only I, fruit a legume or a loment, calyx with odd sepal nearest axis, leaves stipulate—Pea and Acacia family ... ... **Leguminoseae.**

Carpel more than one, generally free, fruit never a legume, calyx with odd sepal remote from axis—
Rose family ... ... **Rosaceae.**

Ovary syncarpous, 4-8 celled, flowers regular, petals clawed and corrugated, stamens definite. Henna family... **Lythraceae.**

Ovary inferior, flower epigynous, regular.

Stamens indefinite, free, flowers 2-sexual, leaves opposite, aromatic and gland-dotted. Guava family ... **Myrtaceae.**

Stamens usually 3 with sinuous anthers, flowers I-sexual, leaves alternate, lobed, plants climbing by tendrils. Cucumber family ... ... **Cucurbitaceae.**

3. **Corollifloreae** or Gamopetalae—corolla gamopetalous, usually with 5 corolla-lobes, stamens equal to or less than corolla-lobes, ovary as a rule syncarpous, superior or inferior.

Ovary inferior, flowers epigynous.

Ovary I-celled with I ovule, fruit a cypsela, anthers 5 syngenesious, fls. in capitula—Sun-flower family ... **Compositae.**

Ovary 2-celled, with 2 or more ovules, stamens 4 or 5, anthers free, fls. not in capitula, leaves with inter-petiolar stipules. Rangun family ... ... **Rubiaceae.**

Ovary superior, flowers hypogynous.

Fls. regular, corolla-lobes, 5, stamens 5, epipetalous

Ovary 2-celled, ovules numerous on prominent peltate placenta, seeds albuminous, embryo small. Potato family ... ... Solanaceae.

Fls. regular, sepals and Petals 5, connate, stamens 5 with pollina

Ovary 2-celled, seeds with hairs, albuminous, Akanda family ... ... Asclepiadaceae.

Ovary 2 or 4-celled, ovules few or only 1 in each cell, seed exalbuminous, embryo large. Twining plants—Morning glory family ... ... Convolvulaceae

Fls. irregular, bilabiate, stamens 2 or 4, didynamous—

Ovary deeply 4-lobed, 4-celled, 4-seeded, separating when ripe, style gynobasic. Toolsi family ... Labiatae.

Ovary 2-celled unlobed, style terminal, fruit capsular, many seeded. Bakash family ... Acanthaceae.

Ovary 2-4 celled, style terminal, Teak family ... ... Verbenaceae.

4. **Incompletae**—Fls. with only sepals, without petals, sometimes entirely naked; often unisexual or bisexual; stamens and carpels few.

Fls. 2-sexual, perianth present, plants herbs.

Perianth conspicuous, gamophyllous, like a corolla, ovary superior, I-celled I-seeded. Krishnakali family ... ... **Nyctaginaceae.**

Perianth dry, minute, scaly, united at base only. Amarantus family ... ... **Amarantaceae.**

Fls. I-sexual, perianth minute or absent, fls. in dense inflorescence, ovary 1 to 2 celled, herbs, shrubs, or trees. Banyan family ... ... **Urticaceae.**

Fls. 1-sexual as above, ovary 3-celled, stigma 3, ovule 1-2 in each cell. Plants with milky or watery juice— ... ... **Euphorbiaceae**

CHAPTER XIX

DICOTYLEDONS.

CRUCIFERAE (Mustard Family).

Distinguishing characters :—

HERBS with pungent juice, and alternate, exstipulate, simple leaves.

FLOWERS regular, cruciform, hypogynous, hermaphrodite, tetramerous, sepals 4, petals 4 clawed.

STAMENS 6, tetradynamous, 4 long and 2 short.

OVARY syncarpous, of 2 carpels, superior. Ovules numerous on two parietal placentas.

FRUIT a siliqua or silicula.

TYPE I—MUSTARD (Rai—*Brassica juncea*).

The plant is an annual herb with a soft juicy stem, slightly woody at the base The lower leaves are petiolate and lyrate, the upper ones sessile and almost entire, with a slightly toothed margin. The root is a short tap-root with a few branches.

The flowers are in racemes, not much elongated but slightly corymbose. They have no bracts, are stalked, and of a bright yellow colour. CALYX of four free sepals, ascending and thus appearing to form a short tube. COROLLA cruciform (p. 107), of four free petals, each with a short stalk and a spreading limb, the limbs of the four petals spread out in the form of a cross. STAMENS six, in two whorls; the outer whorl consists of two short stamens the anthers of which stand just below the stigma; the inner whorl consists of four long stamens with their anthers standing above the stigma at a level with the spreading petal-lobes (p. 105 fig. 173). Between the two short stamens at their base

are two small honey-secreting glands. These constitute the NECTARY. The GYNŒCIUM is composed of two carpels united to form a single syncarpous ovary, a single style and a capitate stigma. The OVARY is superior, free, two-celled with the placenta developed on both sides of the margin of the partition wall. The placentation is really parietal, the OVULES arising from the fused margin of the carpel-leaves, and the wall is only a false septum which makes the ovary falsely two-celled. The FRUIT is a long erect siliqua (p. 142, fig. 242), bursting into two valves, the seeds being attached to the false partition wall which forms a persistent REPLUM. There is no special contrivance for the dispersion of the seed, the plant being in cultivation from very ancient times. The SEED is rich in a fatty oil which can be expressed out and is known as mustard oil.

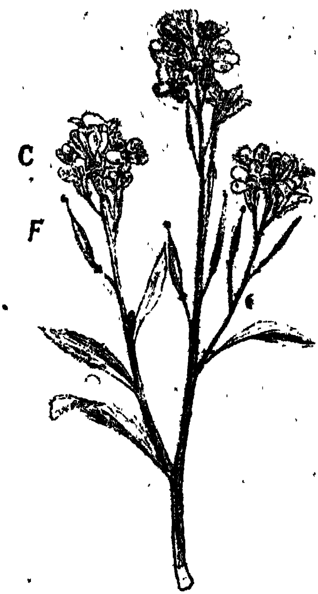


Fig. 337. The Mustard plant; F, fruit; C, inflorescence.

Pollination is effected by the aid of insects. The showy clustered flowers attract them and the glands at the base of the stamens secrete a sweet juice. The flowers are protogynous, the stigma maturing before the anthers; the shorter stamens ripen their anthers before the longer ones. This is to secure cross pollination. So long as the glands are active and a copious juice is secreted, insects come to have their drink; at this time the short stamens discharge pollen which the insects carry away.

When they do not visit, the long stamens simply sprinkle pollen-grains on the sticky style just below (p. 135).

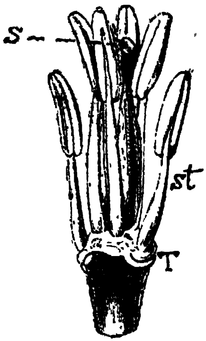


Fig. 338. Tetradynamous stamens ; T, thalamus ; S, stigma.

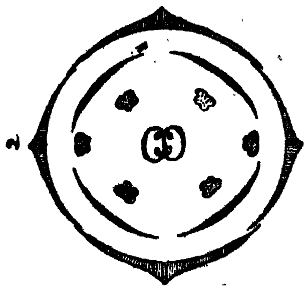


Fig. 339. Floral diagram of Cruciferae.

There are several kinds of the Mustard plant in India. The white Mustard (shwet-sarisa—*Brassica alba*) and the black Mustard (*Brassica nigra*) are winter annuals and have little economic value. The Rape or Coleseed is *Brassica Napus*. It is as extensively cultivated as the Mustard plant. Both yield the same oil ; the Rape has amplexicaul or stem-clasping leaves.

Other Crucifers—The Radish (Moola—*Raphanus sativus*) is another annual herb. Its leaves, like those of the Mustard, are also lyrately simple. The swollen fleshy root (fig. 28) is well known for its nutritious qualities. It abounds in a pungent juice which gives a peculiar sweetish flavour. Cabbages and Cauliflowers (*Brassica oleracea*) are other cruciferous plants. The edible portion of the latter is the young corymbose inflorescence of a peculiarly dense form. The winter annual Candituft (*Iberis*), very often planted in gardens with all its showy varieties, is peculiar for its slightly irregular flowers arranged in beautiful corymbs.

The order derives its name from the cruciform arrangement of the four petals of the flower. It is an order of herbaceous plants, many of which are annuals, while a few are biennials producing a number of leaves on a very short stem in the first season, and in the second, a flowering shoot with the characteristic tetramerous and cruciform flowers. The plants are spread all over the globe, but their widest distribution is in the cold temperate regions and in the hills of India. The crops are all cold-weather crops.

An allied family is the **Papaveraceae** (Poppy family.) The poppy plant (shown in fig. 96) is cultivated for the opium which it yields. Some of the garden poppies are very showy. The common weed Sheal-kanta is called the Mexican poppy (*Argemone mexicana*). All poppies have regular thalamifloral flowers. The stamens are numerous, the superior ovary is syncarpous being formed from many carpels. The style is absent, so the stigma is sessile; it forms radiating lines on the flattened top of the ovary. The fruit is a capsule bursting by pores (p. 142, fig. 243). Opium is the hardened juice which flows from wounds on the surface of the young fruit. The seeds have medicinal properties and yields the poppy oil. Another allied Natural order is the **Capparidaceae**, an order of herbs and shrubs with tetramerous calyx and corolla and generally indefinite stamens. The ovary in this order is stalked and this is a very distinguishing feature. The common plants are the white and yellow Hur-hure (*Gynandropsis pentaphylla*, and *Cleome viscosa*).

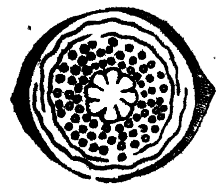


Fig. 340. Floral diagram of Papaveraceae.

MALVACEAE (Cotton family)

Distinguishing characters. – Herbs, shrubs or trees with alternate, stipulate, palmi-nerved, simple leaves.

FLOWERS showy, regular, hermaphrodite, hypogynous; sepals 5, connate, valvate; petals 5, free, lobes contorted in bud.

STAMENS monadelphous, with numerous free unilocular anthers dehiscing transversely.

OVARY superior, syncarpous, 3, 5 or many-celled, with numerous ovules attached to an axile placenta.

FRUIT usually a dry capsule or a schizocarp.

TYPE 1. JAVA—The Shoe flower (*Hibiscus rosa-sinensis*).

The plant is a densely branched woody shrub. LEAVES alternate, stipulate, petiolate, simple, with palmate venation. There are two *stipules* on the two sides of the petiole; they protect the young leaf-buds and fall off with the opening of the leaf. The lamina is ovate, acute, serrate, glabrous, except for a few branched hairs on the underside of the midrib.

The large flowers are solitary, axillary, regular, hypogynous and hermaphrodite. There are two whorls of green sepal-like leaves. Of these the lower consists of six or seven linear bracts and is hence an INVOLUCRE. This whorl is commonly but mistakenly called an epicalyx (see p. 105). The next green whorl consists of five sepals united to form a gamosepalous CALYX, the lobes being valvate in bud. The COROLLA is very conspicuous being of a deep red colour. It is campanulate, the five petals which compose it cohere below slightly and adhering to the stamens form a short cup at the base. The petals are twisted in bud, *i.e.* they have contorted aestivation. The ANDRÆCIUM consists of an indefinite number of stamens; all the filaments cohere

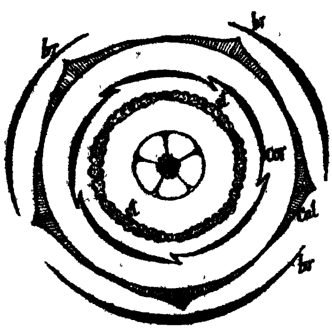


Fig. 341. Floral diagram of Malvaceae; br, bracts, cal, calyx; cor, corolla; st, monadelphous stamens, in the centre the 5-celled ovary.

to form a tube but are free a short distance at the top and so the anthers hang loose from the staminal tube (monadelphous, p. 111 fig. 183). The anthers are free, kidney-shaped, unilocular (fig. 196). The staminal tube surrounds the style and being fused with the petals screens the ovary from view. There are five carpels fused to form a five-celled syncarpous OVARY, a single STYLE branching above into five diverging limbs, each ending in a large round velvety STIGMA. There are numerous ovules attached to the axile placenta. The FRUIT is a loculicidal capsule—the cells being cut lengthwise midway between the partitions.

TYPE II—COTTON PLANT (*Gossypium herbaceum*).

The plant is a perennial bushy shrub with thick, pale green, 3 or 5 lobed palmi-nerved, alternate, simple leaves. The FLOWERS arise singly from the axils of leaves. The young flower-bud is protected by three large cordate bracts which form the EPICALYX (fig. 341). The gamosepalous cup-shaped CALYX has five minute teeth. The five large petals of the COROLLA are bright yellow, usually rendered more attractive by a blotch of dark purple at the base. They are twisted in bud. The numerous STAMENS are monadelphous; the tube adheres to the petals at its base covering the ovary and at first also the style.

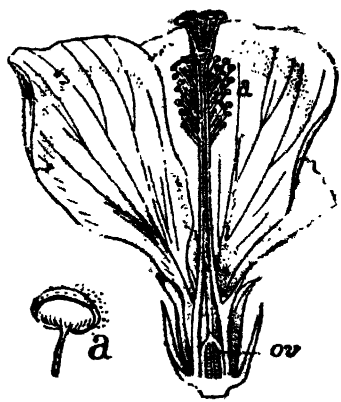


Fig. 342. Flower of *Hibiscus* cut Longitudinally to show the monadelphous stamens adnate to the petals; a, the reniform unilocular anther.

The ANTHER is reniform and unilocular. The long style

lies enclosed by the stamens at its lower part, divides above into five stigmas. The OVARY is five-celled with numerous ovules on an axile placenta. The FRUIT is a dry capsule which bursts loculicidally into three valves (fig. 244). The seed is covered all over with long white twisted hairs (cotton), and is rich in oil. The coat of hairs helps the dispersion of the seeds. **Pollination** takes place with the help of insects which are attracted by the brilliant colour of the petals. The flowers are pollen-flowers (p 124): a large quantity of pollen-grains is produced for the insects to feed on (see also p. 135).

There are two other species of cotton: the Tree Cotton (*Gossypium arboreum*) is a larger plant giving a greater yield of cotton of commerce; the American cotton plant is *G. barbadense* which does not flourish here.

Cotton obtained from the last three plants consists of fine twisted hairs which can be easily spun into threads and is hence of great commercial importance. The **red Silk-cotton tree** (*Shimul – Bombax malabaricum*), however, yields a cotton which cannot be spun and is good enough only for stuffing cushions or mattresses. The Shimul is a large tree with horizontally spreading branches and compound digitate deciduous leaves (fig. 109). The large dark-red flowers are collected in fascicles near the end of the leafless branches. The leaves are shed in winter; the tree remains leafless from December to March; and the flowers appear in January when the tree is entirely leafless. The gamosepalous calyx forms a thick leathery cup. The five large crimson petals are thick and succulent and afford a nutritious food to birds which visit the flower (ornithophilous, p. 126). A sweet thick secretion is collected in the corolla for the birds to drink. **Pollination** takes place through the help of these visitors. The innumerable stamens form five separate bundles which,

however, unite below with the petals and so may be remotely taken to be monadelphous, otherwise pentadelphous. The fruit is a hard, woody, five-celled, five-valved capsule

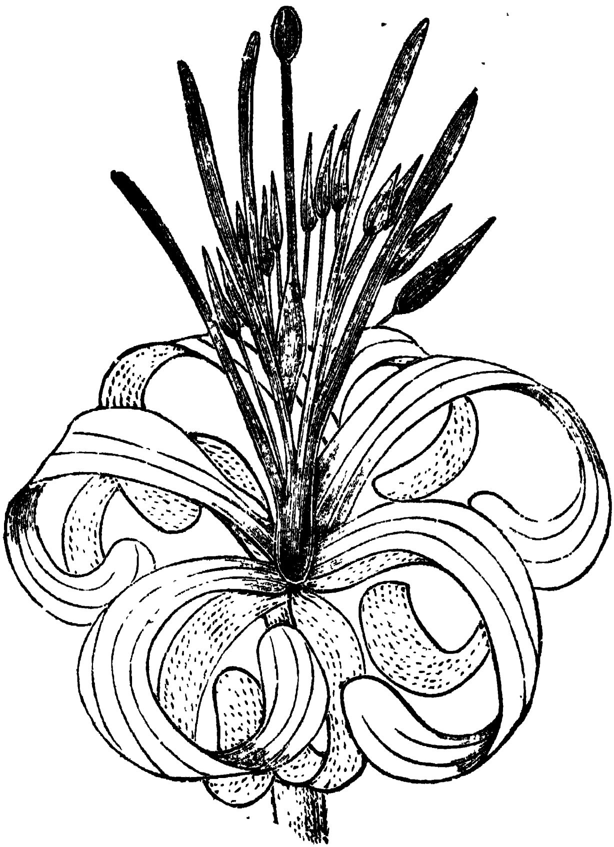


Fig. 343. Flower of Kanak-champa—*Pterospermum Acerifolium.*

The curved dotted leaves are the sepals; these are thick, hairy and fragrant. The stamens are united into a short column with 5 long blade-like staminodes. The ovary is seen in the centre borne on a stalk.

bursting to let go the countless seeds which have a smooth surface but remain embedded in a large quantity of fine silky wool or hairs derived from the pericarp.

A very much similar tree is the **Shwet Shimool,** the white Silk-cotton tree (*Eriodendron anfractuosum*). Like the last this plant also defoliates in winter when it becomes conspicuous by its straight trunk and branches very nearly in whorls. It flowers about March before the leaves appear again in the rains. The flowers are white, otherwise very much like those of the Red Silk-cotton tree, but stamens only 5, connate below into a fleshy tube.

Malvaceæ is a large and important order and it includes many plants of the greatest economic value. The leaves are generally simple and palmately-lobed except in the Silk-cotton trees where they are digitately compound. The epicalyx of three or more bracteoles is also characteristic, though it is not present in all plants of the order. The monadelphous stamens along with the unilocular reniform anthers are the great distinguishing feature. The fruit is also characteristic; in Hibiscus and Gossypium it is a capsule, but in many cases it is a schizocarp separating into cocci (see p. 145). Thus in *Urena lobata* (Okra), a common weed of waste places, the fruit when ripe separates into five indehiscent carples or mericarps.

Besides the cottons other economic plants are the Deccan Hemp (*Hibiscus cannabinus*) which yields from its bark a fibre similar to jute, and the Lady's-finger or Ochra (Dhenras—*H. esculentus*), much cultivated for its fruit which is eaten as a vegetable.

The order abounds in small flowering plants of surpassing beauty. The Chinese-Rose of garden hedges is *Hibiscus schizopetalous.* It has long drooping flowers with ciliated petals. The Sthalpadma or the changeable Rose (*H. mutabilis*) is known for the change of colour, from white to red, which takes place in the flower in the course of a day.

The order Sterculiaceae is very nearly allied to Malvaceæ; monadelphous stamens characterise both orders. The most common Sterculiaceous plant is Kanak-champa (Moochkunda—*Pterospermum acerifolium*—fig. 343), a huge road-side tree. The ovary in this order is stalked (stipitate) and the flowers are generally unisexual, not hermaphrodite as in Malvaceæ (Kanak-champa is hermaphrodite), and the anthers are two-celled.

The following are a few of the other thalamifloral orders.—

Nymphaeaceae—the Lotus and Water-lily family. The plants are aquatic herbs with a rhizomous or tuberous stem lying buried in the muddy soil of ponds. They have long-petioled floating leaves with large roundish lamina. The flowers arise singly on long stalks, are regular, polyphyllous, and hermaphrodite. The lower surface of the leaves is coloured violet or red. This is due to the presence of *anthocyanin* (p. 201) in the cell-sap which helps the leaves in absorbing the heat-rays.

Fig. 344. Nymphæa alba.

Fig. 345. Fruit of Lotus.

The flower of Lotus has been described on p. 92. That of the common Water-lilies (Shalook—*Nymphæa lotus*) differs from the Lotus only in having a syncarpous many-celled ovary. The fruit of the Water-lily is a spongy berry ripening under water and then decomposing to let go the seeds. The seeds float in water being covered with a mucilage and form extensive frothy floating masses. This is for the purpose of dispersion (p. 156). They finally sink and germinate. The fruit of the Lotus, however, is a spongy aggregate fruit (see p. 149, fig. 258).

Anonaceae—the Custard-apple family. The plants which are commonly trees or woody shrubs have simple entire, exstipulate, and alternate leaves. The flowers are regular, hermaphrodite, *trimerous* and

hypogynous; in most cases the thalamus is elongated. There are three sepals, three or six petals, and generally an indefinite number of stamens and carpels. The carpels are free and arranged spirally on the thalamus. The fruit of the Custard apple (Ata—*Anona squamosa*) is a succulent berry; that of the Bullock's heart (Nona—*Anona reticulata*) almost similar (p. 148). The Kantali-champa (*Artabotrys odoratissimus*) is well-known for its fragrant flowers. The plant is a scandent hook-climber (p. 41, fig. 56) and has greenish yellow strong-scented flowers. The fruit (aggregate) consists of a number of fleshy one-seeded berries hanging like a bunch of grapes from the hooked peduncles.

Magnoliaceae—The Champaka family. The plants are trees or shrubs, often climbing, with thick LEAVES which are alternate, simple, usually entire, with bud-scales or stipules covering the buds. FLOWERS are hermaphrodite; aestivation being imbricate. Perianth consists usually of one whorl of three petaloid sepals and two or more whorls of petals of three in each whorl. STAMENS: innumerable, hypogynous. OVARY: many, often few; always unilocular. FRUIT: A collection of follicles or berries with one seed usually in each.

The Swarna champa (*Michelia champaka*) is a tree with large lanceolate, pinni-veined leaves. The leaf-buds as well as the flower buds are enclosed in a greyish scale-leaf—the convolute bud-scale. The flowers arise solitarily and are usually aromatic and showy consisting of a whorl of three petalloid yellowish green sepals and dark golden yellow petals which vary from nine to twenty. The perianth leaves are all arranged spirally on the elongated cone-shaped thalamus. The essential organs of the flower are constituted of innumerable sessile anthers and innumerable carpels which are apocarpous and contain individually an ovary, a short style and the stigma. The flowers are protogynous and come under that group of flowers known as bee-flowers, since they are pollinated by bees. The fruit is a collection of follicles dehiscing by the dorsal suture only. The plant is cultivated in our gardens for its sweet fragrant flowers. (See p. 94, figs. 157, 158).

The N. O. Magnoliaceae very closely resembles the order Anonaceae; the latter however differs from it in having no bud-scale or stipules, the sepals and petals being valvate in aestivation and seeds having ruminated endosperm.

SAPINDACEAE (Lichi family).

Distinguishing characters.—Trees or shrubs, rarely herbs, with alternate, simple or pinnate LEAVES.

FLOWERS small, polygamous, hypogynous, regular or often unsymmetrical, in panicles.

STAMENS free, varying from five to ten, generally 8, inserted between a lateral disk and ovary.

OVARY generally three-celled and three-lobed.

FRUIT capsular or succulent.

THE LITCHI (*Nephelium litchi*).

The plant is a tree with large pinnately compound alternate leaves. The leaflets are lanceolate, very smooth and shining on both sides. FLOWERS arise in large terminal panicles. The individual flowers are small, greenish white, with a gamosepalous four-lobed cup-shaped calyx. COROLLA absent. There is a large fleshy disc-shaped gland in the centre which secretes honey and is hence a nectary. On this the stamens and carpels are inserted. STAMENS from six to eight with free filaments diverging from the central gland. GYNOECIUM superior, syncarpous, elevated on a short style and bifid stigma. OVARY two or three-celled with one ovule in each cell. During the formation of the fruit only one cell persists and one ovule matures into the seed. The FRUIT when ripe has a thin tubercled pericarp and a large seed enveloped by a thick fleshy aril (p. 154) which constitutes the edible part.

Another plant having almost the same floral and fruit structure is the Aash-phal (*Nephelium longana*). Another very common plant is the Napatki or Lata-phatki (*Cardiospermum halicacabum*), a tender climbing herb with ternate leaves and small hooks below the flowers (hook-climber, see p. 39). It has a 3-celled, peculiarly inflated bladder-like 3-valved capsule.

RHAMNACEAE.

Distinguishing characters.—Trees or shrubs, often spiny, with alternate, simple, stipulate LEAVES. FLOWERS greenish or pale, smaller, regular. CALYX gamosepalous, minute, 4-5 cleft, lobes valvate ; PETALS

4-5, smaller than sepals. STAMENS perigynous, as many as the petals and superposed to them. OVARY superior or half-inferior, generally 3-celled. FRUIT a berry or capsule with one seed in each cell.

The KOOL (*Zizyphus jujuba*) is a much-branched, hard, woody shrub with simple, alternate, short-petioled, roundish, serrate leaves which are shiny on the upper and downy on the lower surface. It is armed profusely with sharp spines which represent the stipules. FLOWERS axillary, crowded in small fascicles. CALYX gamosepalous, the 5 calyx-lobes wedge-shaped and concave like spoon. PETALS 5, small. STAMENS five, superposed to the petals and lying in their hollow. At the base of the staminal whorl is a ring-shaped disc with several glands which secrete honey. OVARY superior, syncarpous, with a bifid style and stigma. The fruit is the well-known large smooth fleshy yellow drupe (see p. 146.)

Plants of this order are usually thorny stragglers. Sheakool (*Zizyphus Oenoplia*) is a shruby straggler often found in hedges. The straggling branches are very long and covered with white hairs at the younger parts and armed with exceedingly sharp stipulary thorns.

LEGUMINOSEAE.

This is the second largest order of flowering plants. It includes a wide variety of plants from small annuals to the loftiest trees. The plants are herbs, shrubs or trees with alternate, compound, stipulate leaves. The order derives its name from the fruit which is either a legume or a loment (p. 141). It is divided into three well-marked sub-orders: Papilionaceae, Caesalpineae and Mimoseae. The *distinguishing characters* are :—

	Papilionaceæ	*Cæsalpineæ*	*Mimoseæ*
Flowers......	papilionaceous	slightly irregular	regular.
Petals.........	vexillary	imbricate	valvate.
Stamens......	10, mon-or di-adelphous	10, of which a few are staminodes	indefinite, free.

PAPILIONACEAE.

TYPE I. THE PEA (*Pisum sativum.*)

The plant is a tendril creeper, a very slender annual herb (see fig. 57). The leaves are compound, each consisting of three or four pairs of leaflets arranged on

opposite sides of the common stalk. The terminal leaflets are modified into tendrils which help the plant to get hold of supports. The CIRRHIFEROUSLY PINNATE (p. 59) compound leaves are arranged alternately on the stem, and are provided with large FOLIACEOUS STIPULES (p. 50). The stipules when young protect the leaf- and flower-buds, but as the buds unfold they spread out and perform the function of leaves. They fuse by their margins to form a single flat structure apparently pierced by the stem.

The **flower** (fig. 346) is like a butterfly : it is papilionaceous having a vexillary aestivation (p. 109). The CALYX is gamose-

Fig. 346. A—the Pea Flower. s, the standard ; c, the calyx. B—the same cut vertically showing the stamens and carpel. C—the petals only ; K, the keel ; W, the wings ; s, the standard. D—the stamens, 9 lower united, and the upper one or the tenth free. E—the carpel ; c, the ovary ; st, stigma.

palous, there being a short cup with five unequal lobes. The COROLLA is perigynous, has five free petals, of which the largest is the standard, the two lateral petals form two wings, and the two lower (anterior) are united by their lower margins to form the boat-shaped keel or karina. The ANDRAECIUM consists of the stamens (diadelphous, fig. 185) of which the nine lower ones are united to form a split tube, the split or opening being closed by the tenth free stamen. The ANTHERS are free.

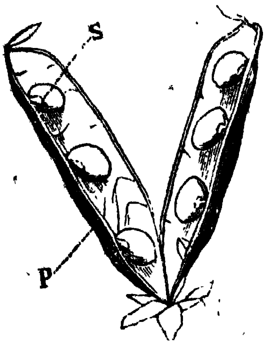


Fig. 347. Fruit of Pea p, pericarp; S, seeds.

The GYNŒCIUM consists of one carpel; the OVARY is elongated, style and stigma simple. The FRUIT is a legume (fig. 347) which bursts both by the ventral and dorsal sutures. The seed is exalbuminous; it has a thin testa and a large embryo, the two cotyledons of which are very swollen and occupy the whole cavity of the seed; a very small plumule lies between them. Pollination is effected by bees (see p. 125).

TYPE II. APARAJITA (*Clitoria ternatea*).

The plant is a rather extensive climber with a wiry stem and numerous branches. The leaves are alternate, pinnately compound with an odd terminal leaflet. They are stipulate, the stipules here being small and membranous, not large as in Pea. There are no tendrils as in the Pea, but the plant climbs by TWINING its stem and branches round supports.

The bluish FLOWERS are solitary, axillary, of the typical papilionaceous form, but has a comparatively large standard and a small keel entirely covered by the wings.

The other floral characters correspond exactly to those of the Pea.

The Papilionaceae, the largest of the three sub-orders of Leguminoseae, includes mostly herbs or herbaceous climbers, though a few are large trees or woody shrubs. Many of the papilionaceæ are climbers: the Pea and the Gram climb by leaf-tendrils, others like the Bean and Clitoria, are twiners. The leaves are always compound, sometimes TRIFOLIATE, with only 3 leaf-lets, but mostly pinnate with several leaf-lets; stipules are always present. The flowers generally arise in racemes.

Common Plants.—All the pulses belong to this order. The Mashkalai (Urid) is *Phaseolus Mungo*; the Moog (Mung) is *P. radiatus*; Kheshari is *Lathyrus sativus*; Masur is *Lens esculenta*; Gram (Chola) is *Cicer arietinum*; Shim is *Dolichos Lablab*—all cultivated annuals with 3 foliate leaves. Besides the pulses the fruits of Barbaty (*Vigna Catjang*), Makhanshim (*Canavalia ensiformis*) and Bean (*Vicia Faba*) are common table vegetables.

The Sun-hemp from which the fibre Shun is obtained is *Crotolaria Juncea*. Sank-alu is the sweet tuberous root of the climber *Pachyrhizus angulatus*. Indigo is obtained by decomposing the leaves of *Indigofera tinctoria*, a small woody plant. *Abrus precatorius*, the Koonch plant, is a hardy shrub which produces the beautiful crimson seed used as small weights by jewellers. Tho Shola plant (*Aeschynemone aspera*) is a water-plant, and yields the Shola of commerce used in making hats and toys.

Of the large tree *Butea frondosa*, the Palas tree, *Erythrina indica*, the Parijat, and *Sesbania grandiflora*, the Bakphul, are well-known for their beautiful gorgeous flowers. *Dalbergia Sisso* is the large timber-tree Sissoo, while *Pterocarpus Santalinus* is the red santal-wood tree.

CAESALPINEAE.

The Tamarind (*Tamarindus indica*) may be taken as a type. It is a large tree with pinnately compound leaves. *Flowers* in racemes, strikingly irregular with only three petals streaked with red and yellow, and three fertile stamens and a few short sterile staminodes. The stalked petals spread out like the wings of butterfly. The fruit is the well-

known indehiscent legume with transverse constrictions, full of a soft acid pulp (p. 142).

Another very common plant of this family is the Indian Laburnum tree (Soondali or Sundulay—*Cassia fistula*). It has very beautiful pendent racemes of large golden yellow flowers. The fruits are long rod-shaped indehiscent legumes the pulp of which is used as a purgative. The Gold-mohur tree (*Poinciana regia*), often planted on roadside, produces very showy and large flowers. The flowers are produced in the hot season just before the rains, and in such profusion that the extensive canopy of the tree looks as if covered with a lilac-coloured vesture which gives a surpassing beauty to the trees. These plants have usually ten stamens some of which, however, are sometimes abortive. The Asoka tree, well-known for its crimson flowers, is *Saraca indica*; the flowers are heptandrous. The Kanchan (*Bauhinia*) is a shrub or small tree with beautiful white or coloured flowers; it is peculiar in having simple leaves. The leaf has a wide notch at the top making it appear as if composed of two fused leaves; hence the Sanscrit name Jugma-patra given to the plant. Kal-kasonda (*Cassia occidentalis*) is a small shrub very common on road-sides and waste places. Krishna-chura (*Caesalpinia pulcherrima*) is another large tree with beautiful flowers.

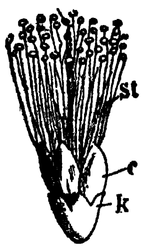


Fig. 348.
Flower of Babla.

MIMOSEAS.

The Babla (*Acacia arabica*).

The plant is a hard woody arborescent shrub or a small tree. The leaves are compound and bi-pinnate; the leaflets are small and fold up at night. The leaves are alternate and stipulate as in other Leguminosæ, but the stipules here are transformed into spines. The bark of the tree is well-known

for its astringent property which is due to the presence of tannins for which it is used in leather factories for tanning leather. The ordinary gum of commerce is the exudation from the bark of this plant.

The FLOWERS are small but densely clustered in round heads (fig. 147). The latter look like single flowers and are yellow. A single flower from the head is shown in fig. 348. The calyx is a minute cup (K). The corolla (C) consists of four or five minute petals. STAMENS (St) innumerable, with their filaments free, and bright yellow anthers standing high above the flowers. The filaments radiate on all sides and give the peculiar beauty the small flower-heads have. The FRUIT is a flat grey legume constricted between the seeds so that it appears like a string of beads.

The Sensitive plant (the Lajjabuty—*Mimosa pudica*) is a small shrub. It is remarkable for the peculiar sensitiveness of its leaves to external stimuli. The STIPULES are not quite spiny, but thorny prickles arise from the base of the leaves. The FLOWERS are structurally very much like those of the Acacia but the small heads are of a light rose colour. FRUIT a loment (p. 142).

ROSACEAE (Rose family).

Distinguishing characters.—Trees, herbs or shrubs with alternate, stipulate, compound pinnate leaves.

FLOWERS regular, rosaceous, perigynous or hypogynous, hermaphrodite. CALYX 5-fid, PETALS 5, free.

STAMENS many, free.

OVARY superior, half-superior or inferior, apocarpous, rarely syncarpous.

FRUIT a collection of achenes or drupes, or a single drupe where there is only one carpel (Peach).

The GARDEN ROSE. (*Rosa centifolia*).

The plant is a small shrub with woody stem which is armed with many prickles. The LEAVES are compound with two or three pairs of leaflets and an odd terminal one (imparipinnate, see fig. 53). They are provided with two lateral STIPULES which run a short distance up the petiole (adnate stipules). In bud the leaves are folded along the midrib (conduplicate vernation, p. 68).

The **flowers** are solitary and terminal, regular, hermaphrodite. If a longitudinal section be cut (fig. 159) it will be seen that the calyx arises from a cup-like receptacle containing numerous carpels. The five sepals arise from the margin of this receptacle. On it also lie the numerous petals and but a few stamens. In wild Rose there are but five petals and numerous stamens; the latter, however, are transformed into petals in cultivation. Thus the garden Rose is a double flower (p. 97). The aim of the gardener is to produce large compact Roses with all the staminal leaves converted into petals. The GYNŒCIUM is composed of many free carpels which form separate ovaries all lying inside the hollow receptacle. There are as many styles and stigmas as there are ovaries. The FRUIT is an aggregate fruit and is known as the Rose-hip (p. 150). It is really a collection of one-seeded achenes which ripen from the apocarpous ovary. The receptacle becomes fleshy and forms a sweet pulp which attracts birds. The small seed-like fruits are dispersed by birds.

Other Rosaceous plants are the Apple—*Pyrus malus*; Pear—*Pyrus communis*; Peach—*Prunus persica*; Loquat—*Eriobotrya japonica*; Almond—*Prunus amygdalus*, etc.

MYRTACEAE— (Guava family).

Distinguishing characters.—Trees or shrubs with opposite, simple, entire LEAVES with glandular dots containing aromatic oils.

FLOWERS regular, hermaphrodite, epigynous with 4 or 5-merous perianth.

STAMENS indefinite, free. OVARY inferior, 2-celled, placentation axile, ovules one or more.

FRUIT a capsule or a succulent berry.

TYPE I. GUAVA (*Psidium guava*).

This is a small evergreen tree with whitish scaly bark. LEAVES opposite, simple, entire, short-petioled, exstipulate. The veins of the leaf unite into a nerve which run parallel to the margin. This is the SUB-MARGINAL vein so characteristic of the order. The FLOWERS arise singly or in clusters of two or three, are large, white, and epigynous. The CALYX forms a tube adnate to the wall of the ovary and has four or five lobes arising from the top of the latter. PETALS of an equal number, free. STAMENS epigynous, numerous; the filaments slender, bent inwards before the flower opens. The GYNŒCIUM is syncarpous; the ovary inferior, adnate to the calyx-tube, with 4 or 5 cells; placentation axile. The FRUIT is an inferior berry with the calyx-lobes persisting as dry scales at the top. SEEDS numerous, hard, imbedded in the pulp of the fruit.

TYPE II. JAM OR JAMON (*Eugenia Jambolana*).

The plant is a middle-sized tree with opposite, oblong, entire, exstipulate leaves with veins running into a nerve parallel to the margin. When the leaf is held up to light little transparent dots are seen; these are glands containing a volatile oil which emit an agreeble odour when the leaf is bruised. The white small FLOWERS arise in compound trichotomous cymes from the axils of fallen leaves. The CALYX is represented by four small lobes arising from the top of the ovary. PETALS four, inserted on a small

disc within the calyx, caducous, *i.e.*, they fall away as soon as the flower-bud opens. STAMENS numerous, long, coloured and showy. OVARY inferior, two-celled, adnate to the hollow thalamus. Style single with a small stigma. FRUIT is a drupe with one large seed. When crushed by the teeth the seed has a bitter taste and hence birds which eat the fruits do not try to eat the seed. The pulpy part is of a violet colour, the thin skin being black.

Myrtaceae is an order of tropic evergreen plants which are hard and woody and have generally small shiny coriaceous leaves. The leaves are mostly opposite (alternate in *Eucalyptus*), and the glandular dots and sub-marginal veins are very characteristic of the order. The plants are generally aromatic and some yield valuable oil contained in the oil-gland of the leaves. Eucalyptus, Clove, Myrtle, and Cajeputy Oils are instances. The order abounds in lofty trees: some of the Eucalyptus trees of Australia attain a height of 300 to 400 ft!

The epigynous flowers with their numerous long coloured stamens are very attractive, not so much for the petals as for the countless stamens which stand in beautiful bunches. The inferior ovary is crowned by a flat disc; it may be 1-celled with 1 or more ovules, or 2 or more-celled with numerous ovules. Fruit is either a dry capsule (Eucalyptus) or a berry (Guava, Jams).

Other important plants:—(1) The Rose apple (gulabjam) is *Eugenia Jambos*; (2) the white Malay apple (Jamrul) is *E. Malaccensis*—both cultivated for the fruits. (3) Cloves (Lavunga) are the dried flower-buds of *Eugenia Caryophyllata*. (4) Cajeputy oil is derived from the leaves of *Melaleuca Leucadendron*.

A few others are ornamental garden plants.

An allied order is **Lythraceae** where, however, the leaves are not gland-dotted, nor do they possess any sub-marginal veins. The most common plant is the shrub Menthy or Henna (*Lawsonia innermis*), the crushed leaves of which are used by Indian ladies for decorating their finger nails. The large timber tree Jarul (*Lagerstraemia flos-regina*) has very beautiful, large, rose-coloured flowers. The petals

of these plants are stalked and crumpled up or corrugated which makes them exceedingly nice looking.

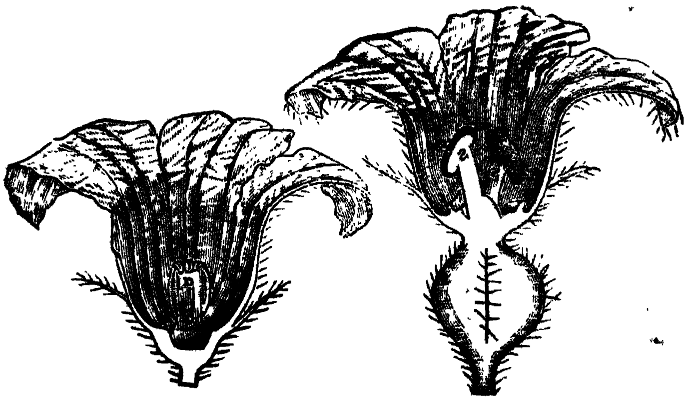


Fig. 349. Male flower of the Pumpkin cut vertically, in the centre the stamens.

Fig. 350. Female flower of same cut vertically, the swollen part is the inferior ovary; S, the stigma.

CUCURBITACEAE—(Cucumber family)

Distinguishing characters.—Herbaceous climbers with axillary or lateral tendrils. LEAVES simple, alternate, exstipulate, large, cordate, palmately lobed.

FLOWERS regular, unisexual, epigynous.

CALYX and COROLLA usually gamophyllous, 5-lobed.

STAMENS usually 3, rarely 5, 2 pairs of which unite to form 2 thick filaments and 1 free, forming altogether 3 filaments. Anthers usually syngenesious, sinuous.

OVARY inferior, 1 celled, with 3 parietal placentas which sometimes project inside and make the ovary falsely 3-celled; *ovules* many; style 1, stigma 3.

FRUIT a berry, or a large pepo.

TYPE I. CUCUMBER (*Cucumis sativus*).

The plant is a herbaceous climber with a hollow five-

edged succulent stem. It climbs by means of long thin branched *tendrils* which arise from the base of the leaves and are hence modified branches. The young tendrils are always

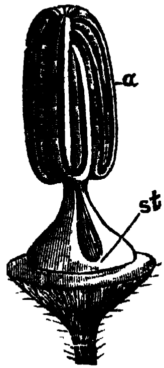


Fig. 351. Male flower of pumpkin with perianth removed ; st, the three stamens ; a, anthers.

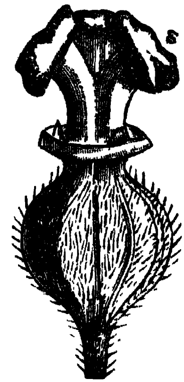


Fig. 352. Female flower of same with perianth removed ; S, stigma, the swollen part is the inferior ovary.

making spontaneous movements in air till they come in contact with some support which, if of suitable thickness, is at once clasped. The *leaves* are large, broad, cordate, petiolate, alternate and simple. Fine bristly hairs cover the whole plant excepting the tendrils. As in many climbers, the plant has often to trail on the ground and then its leaves twist their petioles variously so that the lamina is laid flat. The leaves being large are protected from being torn up by wind by having a strong rib going from the top of the petiole to the separate lobes, thus giving to each lobe a separate network of the supporting tissue.

The **flowers** arise singly or in small clusters from the leaf-axils. The calyx and corolla are united at their base. CALYX gamosepalous, campanulate. COROLLA is regular, epigynous in the female flower, and campanulate in shape ;

in the male it is provided with a lobed disc at the base. Male and female flowers are formed on the same plant (monœcious. p. 110). STAMENS in the male flower only three. epipetalous; two filaments more or less united in pairs, and the anthers convoluted and laterally united. In the female flower there are small glands at the base of the corolla which represent the abortive stamens: they secrete honey. The GYNOECIUM is composed of three carpels fused to form a syncarpous inferior ovary with a short style and three stigmas. The calyx arises from the flat top of the hollow thalamus which encloses the ovary. The inferior ovary is one-celled with three prominent parietal placentas which bulge towards the centre and bear numerous ovules (see p. 149). FRUIT, technically called a pepo, is a large berry with leathery rind and numerous seeds. Seeds compressed, exalbuminous, with a large embryo.

The flowers are **insect-pollinated.** Insects carry the pollen from the male flower to the stigma of the female. To attract them a sweet liquid is secreted by the small glands at the base of the corolla. Insects attracted by the bright colour of the corolla move about from flower to flower seeking the sweet secretion and collecting pollen and thus bring about inter-crossing (see p. 124).

The order is characterised by the peculiar climbing habit of the plants, the unisexual flowers, and the inferior pepo or berry-like fruits. The plants are climbing herbs with hollow stems and simple or divided tendrils. The large broad palmately-veined leaves are always covered with coarse stiff hairs. Some plants are diœcious (p. 111)—*e.g.*, Patol (*Trichosanthes dioica*) but the great majority are monœcious.

Common Plants :—Many plants of this order are cultivated for their fruits which are either table delicacies or kitchen vegetables. Of the vegetables the most common are the Lau or Kudoo (*Lagenaria Vulgaris*), and the Kumra (white or Chal-kumra—*Benincasa cerifera*). Other plants are :- *Cucumis melo*, the Musk Melon (Kharbooj);

Cucurbita maxima, the Gourd (Belati Kumra); *Cucurbita pepo*, the Pumpkin; *Citrullus vulgaris*, the Water-melon (Turbooj). Of the bitter vegetables *Luffa acutangula* (Jhinga) and *Momordica charantia* (Karela) are used in Indian curries. *Cephalandra indica* (Telakucha), a wild hedge-climber, produces very beautiful red berries which are greedily eaten by birds. A similar plant is the Makal (*Trichosanthes palmata*).

RUBIACEAE (Rangun family).

Distinguishing characters.—Trees, shrubs or herbs with entire, simple, opposite LEAVES having interpetiolar stipules.

FLOWERS regular, hermaphrodite, gamopetalous, epigynous, often 4-merous.

STAMENS 4 or 5, epipetalous, alternating with corolla-lobes.

OVARY inferior, two-celled with two or more seeds.

TYPE I. RANGUN (*Ixora coccinea*).

A common bushy garden shrub planted for its delightful cluster of flowers. The STEM is hard, woody and much-branched. The LEAVES are opposite, almost sessile, oblong, entire, tough and leathery. Between the abbreviated petioles lie two scarious STIPULES, one on each side. These are the interpetiolar stipules so characteristic of the order.

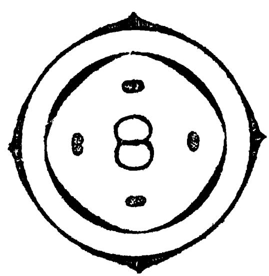


Fig. 353. Floral diagram of Rubiaceæ, showing the tetramerous calyx, corolla, and stamens, and dimerous ovary.

The flowers arise in dense clusters at the end of the short twigs in dichasial cymes which are highly attractive for their scarlet colour. The CALYX has a small tube adnate to the wall of the ovary, and is represented by only four minute teeth (fig.180). The gamopetalous COROLLA has a long slender tube spreading above into a four-parted limb. These corolla-lobes remain twis-

ted in the bud. STAMENS four, inserted in the mouth of the corolla-tube alternating with the lobes. The filaments are very short so that the anthers appear almost sessile. GYNŒCIUM consists of two united carpels, a single long style, and a bifid stigma. Ovary syncarpous, inferior, two-celled, each containing one ovule. The FRUIT is a succulent scarlet-coloured drupe with two small 1-seeded stones. Seeds with horny or fleshy albumen.

Pollination takes place with the help of insects. Honey is secreted by a small disc round the base of the style. Only bees and butterflies provided with long tongues can pollinate. For, the nectar is secreted a long distance away from the mouth of the tubular corolla and can only be reached with a tongue of corresponding length. A long-tongued bee, while creeping over the dense floral clusters and dipping here and there for having a sip, brings its head in contact either with the anthers or with the bifid stigmas of different flowers. Inter-crossing is often geitonogamous (p. 128).

TYPE II. KADAMBA (*Anthocephalous cadamba*).

The plant is a huge tree with very large prominently penni-nerved, simple, opposite, petiolate LEAVES. The STIPULES are caducous; they protect the young terminal buds of the shoot but fall away as soon as the stem elongates. The FLOWERS are clustered in very attractive globose heads. of the size of tennis balls. The numerous STYLES and STIGMAS, projecting far above the flowers, form a white fringe which heightens the beauty of the cluster. The minute calyx has a five-parted limb; corolla is small, funnel-shaped. Stamens 4, very long; style of equal length, bifid. The flowers are presumably pollinated by bats and birds, the juicy stamens affording food. The FRUIT is an inferior, four-sided, two-celled, many-seeded capsule.

Other Rubiaceous plants are :—Gandharaj (*Gardenia florida*), a

much branched tree with large, solitary, axillary, fragrant, white flowers; the flowers here are not tubular as in the last two cases and very frequently become doubled (p. 97). The Manjeet (*Rubia cordifolia*) is a climbing herb. The well-known Cinchona plant (*Cinchona succirubra*) yields quinine from its bark. Sadapata (*Mussaenda corymbosa* is a small shruby plant peculiar on account of the striking development of one of the calyx-lobes as a large white leaf. The well-known Coffee plant (*Coffea arabica*) is cultivated for the coffee which is obtained from the seeds.

The interpetiolar stipules (fig. 79) of Rubiaceæ are very distinctive of the whole order. The stipules sometimes become large and leaf-like (FOLIACEOUS) and form with their leaves a false whorl round the stem (Munjeet).

COMPOSITAE (Sunflower family).

Distinguishing characters.—Herbs with simple, **alternate** or opposite leaves.

FLOWERS epigynous, gamophyllous, aggregated in capitula.

STAMENS five with syngenesious anthers.

OVARY inferior, 1-locular, with one ovule.

FRUIT a dry indehiscent cypsela with persistent calyx, often in the form of pappus.

TYPE I. SUN-FLOWER (*Helianthus annuus*).

There are many varieties of the Sunflower cultivated in gardens. All are herbs with a herbaceous, hairy, hollow stem. The LEAVES are simple, alternate, exstipulate, petiolate, large, slightly cordate at the base, ovate-acuminate, and rough with stiff hairs. The margin is broadly serrate; there are two strong lateral veins on the two sides of a strong midrib.

The stem and branches terminate in large CAPITULA (p. 79, fig. 133) which turn their faces towards the sun (hence the name Sunflower). There are two kinds of

flowers: those on the circumference of the capitulum are large and strap-shaped or ligulate—these are the RAY-FLORETS; those inside the circle, seated sessile on the flat sur-

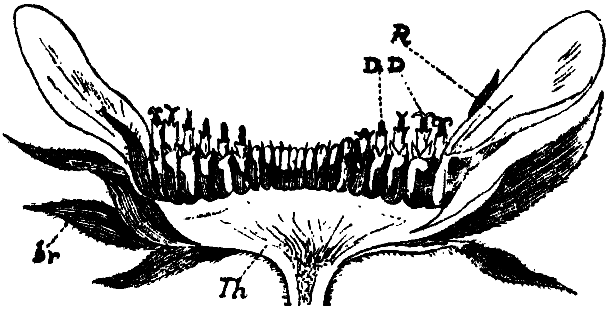


Fig. 354. Capitulum of Sun-flower cut vertically to show: Th, the rachis; br, the involucre of bracts; R, the ray-florets; D,D, the disc-florets.

face of the receptacle, are small and tubular—these are the DISC-FLORETS (see p. 86). All the FLORETS are epigynous, the ovary being enclosed within a hollow thalamus the rim of which forms the calyx-tube. Each floret is subtended by a small, thin, white scale which is a bract and is known as the PALEÆ (p. 81, fig. 137). The flower cluster is surrounded on the outside by whorls of small green leaf-like bracts—these constitute an INVOLUCRE (fig. 133).

The RAY-FLORETS are irregular and unisexual, being pistillate. The tubular CALYX is not apparent being adherent to the inferior ovary. There are, however, two small scales at the base of the corolla which represent the calyx-lobes. The COROLLA is gamopetalous; there is a very short tube at the base which appears to be split at one side and then the corolla spreads out in the form of a long flat lip. The tip of this ligulate corolla is here acute but in other plants of the family has 3 to 5 indentations which represent so many petals. (See figs. 171, 176).

The DISC-FLORETS are regular, tubular, swollen at the base with five corolla-lobes representing the petals, and are hermaphrodite and epigynous. ANDRŒCIUM consists of five epipetalous stamens springing from the corolla with free filaments and cohering anthers (syngenesious, p. 111, see fig. 186). Calyx as in the ray-florets.

Fig. 355. Garden Sunflower.

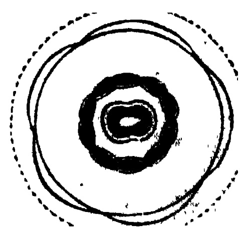


Fig. 356. Floral diagram of Compositæ. The outer dotted circle represents the pappose calyx, next comes the circle of corolla-lobes. The third circle represents the syngenesious stamens. In the centre is the 1-celled ovary with a single seed.

The GYNŒCIUM of all the flowers consists of two carpels which form a syncarpous inferior ovary, a single style, and a bifid stigma. The ovary is unilocular, contains only one erect ovule, and matures into a CYPSELA (p. 143, see fig. 245). The calyx persists in the form of two very short membranous wings on the top. SEED exalbuminous, has two large cotyledons between which nestles a small plumule.

Pollination:—The flowers open very gradually from the circumference to the centre. They are protandrous (p. 129), and are pollinated by insects (Bees). The ray-

florets serve to make the inflorescence conspicuous; the countless disc-florets produce a large surplus of pollen which is collected by Bees as they crawl over the cluster. The pollen is discharged inside the tube formed by the coherent anthers over the head of the still elongating immature style. This is provided with hairs on the outside, and the hairs catch the pollen-grains, so the style at this stage appears somewhat like a paint-brush. At first the elongating style sweeps the pollen above so that insects crawling over the flowers get it easily (see figs. 223—26). After some time the style bifurcates and the stigma is ripened. Now the pollen is almost beyond the reach of the insects, because the tip of the style is now reflexed. As the insects trample on all the flowers, the pollen from the younger ones reaches the older florets which are ready with their bifid stigma. On the failure of inter-crossing self-pollination takes place, as has been described on pp. 133 and 135.

Other Compositæ plants having almost the same floral structure are Marigold (Genda —*Tagetes Patula*) and Zinnia (*Zinnia Elegans*). In these plants, however, the flowers are frequently doubled. In Zinnia the leaves are opposite and sessile; those of Marigold are alternate but imparipinnately compound.

Type II. KUSUM (Safflower—*Carthamus tinctorius*).

The plant is an annual (winter) herb with many axillary branches. Leaves simple, alternate, exstipulate, sessile, broad-lanceolate with deeply cut spinous margins. The flowers form small heads which in the bud are perfectly globular. The involucral bracts form very compact imbricate whorls armed with spines and bristles. There are no strap-shaped ray-florets. The flowers are all of the same form, gamopetalous, irregularly bell-shaped, with five corolla-lobes. The small bracts which subtend the individual flowers (paleæ) are foliaceous. Andrœcium and gynœcium as in the last type.

The plant is cultivated for the sake of a brilliant dye (CARTHAMIN) obtained from its deep orange flowers, also for the oil which can be expressed out of its seeds.

The **Compositae** forms a very well-defined natural order of plants characterised by their inflorescence, the syngenesious stamens, and inferior uni-locular ovary with one ovule; the calyx is often indistinguishable but sometimes forms a tuft of hairs crowning the ovary and the fruit—this is called the pappus (figs. 352-3). Another very characteristic feature, though not of importance in classification, is the presence of INULIN instead of starch in the subterranean parts (p. 196).

Other common plants of the order are,—the **Chandramullika** (Chrysanthemums), highly prized for their elegant flowers; *Vernonia cinerea* (Kokshim) is a very common weed of waste places; *Enhydra fluctuans* (Hingcha) is a water-plant often taken as a remedy for flatulence and sleeplessness.

SOLANACEAE (Potato family)

Distinguishing characters.—Herbs or shrubs with simple or pinnate, alternate, exstipulate LEAVES.

FLOWERS regular, gamopetalous, pentamerous, hermaphrodite, hypogynous. STAMENS five, epipetalous.

Fig. 357. Flower of Potato; st, stamens; s, the stigma.

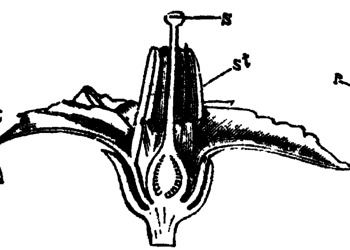


Fig. 358. The same cut vertically; st, stamens; s, stigma.

Fig. 359. An anther of same showing porous dehiscence; p, the pollen.

OVARY superior, two-locular, with a prominent axile placenta bearing numerous ovules.

MITRA'S ELEMENTARY BOTANY

Capsicum frutescence—The Lunka

1 THE PLANT 2 THE FLOWER 3 SECTION OF FRUIT

.A PRESS

FRUIT a berry, less often a capsule, with numerous seeds.

TYPE I. THE POTATO (*Solanum tuberosum*).

The plant is a small annual herb cultivated for its tubers (p. 33, fig. 40) which are swollen portions of underground stoloniferous branches. LEAVES large, simple, pinnately lobed; between the larger lobes are smaller ones, the terminal lobe being the largest.

Flowers solitary, axillary, regular and hypogynous. CALYX consists of 5 sepals united at the base to form a flat cup. COROLLA rotate, gamopetalous with five spreading lobes: the latter are plaited and twisted (p. 109) in bud. STAMENS epipetalous, alternating with the corolla-lobes, with large coherent anthers which dehisce by apical pores (p. 113). GYNŒCIUM consists of two carpels united to form a superior syncarpous ovary, a single style, and

Fig. 360. The Brinjal plant.

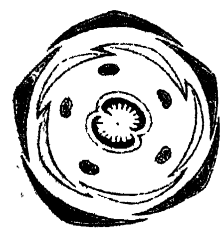


Fig. 361. Floral diagram of Solanaceæ. Note the contorted corolla; and the prominent swollen axile placenta.

a simple stigma. The ovary is two-celled with numerous ovules attached to a prominently peltate axile placenta. FRUIT is a round green berry with many seeds.

The Brinjal plant (*Solanum melongena*—Bagun), well-known for its large berries, has a very similar floral structure. The leaves, however, are not lobed but are simple and peculiar in having several stiff prickles on its lower surface. Another plant having a similar floral structure is the common weed Kantikari (*Solanum xanthocarpum*). It is a prickly herb with pinnatifid leaves which are very spinous, the lobes being drawn out into hard spines. It has small bluish rotate flowers and yellow spherical berries streaked with white lines. The Capsicum (Lunka—*Capsicum frutescens*) has also a similar floral structure. The fruit is a long dry berry.

TYPE II. THE TOBACCO (*Nicotiana tabacum*).

The plant is a small herb covered with sticky glandular hairs. The large LEAVES are simple, alternate, entire, and

Fig. 362. The Datura plant.

of varying size. The FLOWERS arise in terminal cymose fascicles, are either white or red. Floral structure same as given before, but the COROLLA is bell-shaped and

elongated (not rotate as in the various species of Solanum) with the plaited aestivation peculiar to the order. The five STAMENS are epipetalous, alternating with the corolla-lobes, the adhering filaments forming ridges on the corolla. The fruit is a capsule, bursting into two valves.

The Datura (*Datura stramonium*) is a common weed with large unsymmetrical leaves. The corolla (p. 108, fig. 181) forms a large funnel of a pure white colour giving out a sweet fragrance at night-fall. It is a moth-flower (see p. 125). The fruit is peculiar in having four chambers, solanaceous fruits being usually two-celled. The Datura fruit is a capsule like that of the Tobacco, but it bursts into four valves (fig. 239). It is covered all over with prickles which serve to protect the young fruit. The flattened seeds are highly poisonous.

SOLANACEOUS plants are generally poisonous being rich in alkaloids. The poisonous principle lies generally in alkaloids. Thus, Datura seeds contain the deadly alkaloid DATURINE; Tobacco seeds, as well as every part of the plant, contain the toxic alkaloid NICOTINE; the American Belladona plant ATROPINE and so on. Even the Solanum plants contain a poisonous substance named SOLANINE. By long cultivation, however, most of the plants—those which form esculent vegetables—have lost their poisonous property—*e.g.*, the Potato, the Brinjal, the Tomato (Belati Begoon.—*Lycopersicum esculentum*) and Tepari (the Cape Gooseberry—*Physalis peruviana*). The latter has a very peculiar fruit which is a berry enveloped by a thin papery bladder (accrescent calyx, p. 105). The Kantikari (*Solanum xanthocarpum*),—a prickly herb of waste lands, and the Aswagandha (*Withania somnifera*), a cultivated plant, are used in Hindu medicine, the latter yielding the Aswagandha wine.

ASCLEPIADACAE (The Akanda family).

Distinguishing characters :—The plants are herbs or shrubs, often twiners, with milky juice. The *leaves* are entire, opposite, petiolate and exstipulate.

Flowers :—Regular, pentamerous, contorted in bud; the throat of the corolla bearing a circle of hairy outgrowths called 'corona'.

Stamens :—Five, gynandrous; filaments uniting together to form a hollow tube which encloses the style; pollen-grains are aggregated to form distinct pollinia. (p. 113).

Carpels :—Two, distinct or coherent below; stigmas forming a pentagonal shield-shaped structures to which the anthers are adherent.

Fruit :—A pair of follicles often one by abortion; containing numerous comose or hairy seeds.

AKANDA OR MADAR.—(*Calotropis gigantea*).

The plant is a shrub and grows everywhere in tropical regions. The surface of the stem as well as of its leaves is covered with white waxy hairs and anatomically very rich in latex-containing glands. (P. 186 and fig. 276D) The leaves are entire and opposite and remain green even in the hottet and driest parts of the year. The flowers of the plant are found clustered in umbellate inflorescence. The calyx consists of five connate inferior sepals, the corolla of five connate valvately lobed petals on which stands adnately the corona—a crown-shaped structure. (p. 107). POLLINATION takes place with the help of flies (fly-flowers, p. 125). The pollinia is attached to sticky glands at the corner of the pentagonal stigma. Insects alighting on the broad stigma in search of nectar carry off several pollinia with their feet to another flower and thus brings about the fertilisation. The resulting fruit is a pair of follicles with numerous seeds which are provided with a tuft of 'Coma' at the hilum—a suitable mechanism known as parachute mechanism for their dispersion. (Fig. 233; p. 157). The plant is economically important for the immensely strong fibres obtained from its stem. Other plants are *Calotropis procera*, Sada-Akanda; *Stephanotis floribunda*, a large garden climber with handsome flowers; and the Anantamul or Indian Sarsaparilla, *Hemidesmus indicus*, a shruby twiner.

CONVOLVULACEAE (Morning-glory family).

Distinguishing characters.—Twining herbs or shrubs with alternate, simple, exstipulate, cordate LEAVES.

FLOWERS large conspicuous, gamopetalous, hypogynous, hermaphrodite, with contorted aestivation.

STAMENS five, epipetalous.

OVARY superior, usually two-celled, with two ovules in each cell, or 4-celled with 1 ovule in each cell.

FRUIT a capsule or berry. Seed exalbuminous, with the embryo having crumpled green cotyledons.

KALMI-SHAK – (*Ipomoea reptans*).

The plant is an aquatic annual herb with very long, jointed, hollow, smooth stem floating on the water, and alternate long-petioled, cordate, oblong or sagittate, entire, simple LEAVES. FLOWERS arise in small three or six-flowered fascicles or umbels. They are large, of a beautiful rose colour. CALYX consists of five sepals, united at the base to form a short cup. COROLLA large, gamopetalous, bell-shaped with five lobes representing the petals. The corolla-lobes are folded along the median lines (representing midribs) and twisted in the bud (aestivation plaited-contorted). STAMENS five, epipetalous, free, alternating with the lobes of the corolla. GYNŒCIUM of two carpels forming a superior ovary, a single style and two globose stigmas. OVARY two-celled with two ovules in each cell. Fruit a globose capsule.

There are several other *Ipomoeas* :—The Sweet Potato (Sakarkand-aloo—Ranga-aloo—*Ipomoea batatas*) is a creeping herb cultivated on account of its tuberous roots which store a large quantity of starch and sugar. *Ipomoea bona-nux* (the Moon flower) is an extensive twiner ; it has large white flowers which open at dusk and emit a far-reaching fragrance. *Quamoclit pinnata* (Toru-lata) is a small annual twiner with much divided leaves, the leaflets looking like long flattened needles. The flower has a funnel-shaped corolla of a brilliant red colour.

The parasite Cuscuta mentioned on pp. 25 and 304 is another convolvulaceous plant.

LABIATAE (Toolsi family).

Distinguishing characters.—Herbs with square stems and simple opposite decussate LEAVES.

FLOWERS clustered in verticillasters. Flower irregular, bilabiate, gamopetalous, hermaphrodite, hypogynous.

STAMENS four, didynamous, rarely diandrous.

OVARY deeply four-lobed, 4-celled, with 1 ovule in each cell, stigma bifid, style gynobasic.

FRUIT of four dry achenes seated in a persistent calyx.

TYPE I. THE TOOLSI (*Ocimum sanctum*).

The plant is a small woody perennial *herb* with square stem and branches. LEAVES simple, decussate, exstipulate, petiolate, elliptical with serrate margin. When crushed between the fingers the stems and leaves give out a characteristic odour. This is due to the presence of an ETHEREAL OIL secreted by small glandular hairs scattered over the surface of the stems and leaves.

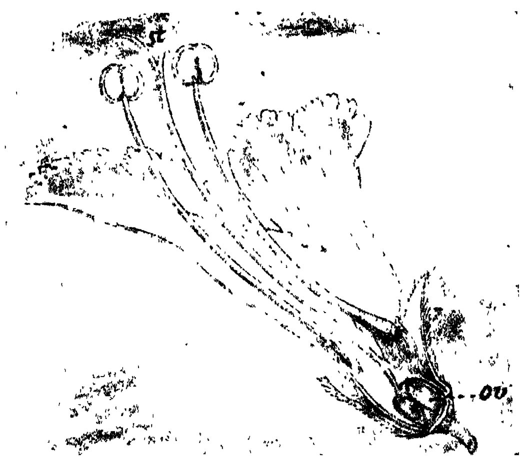


Fig. 363. Flower of Labiatæ, longitudinal section; showing the four-lobed ovary (ov) with gynobasic style and bifid stigma (st).

The flowers form small cymes in the axils of the opposite leaves, the whorl being called a VERTICILLASTER (p. 88; fig. 151). The separate cymes forming the whorl may be

isolated and their cymose nature determined. It will be found that a central flower opens first: there are usually three pairs of such cymes. The verticillasters are in their turn arranged on an elongated stem and develop acropetally. Hence the whole inflorescence is a mixed one—it is a system of verticillasters developed racemosely.

Each small FLOWER is short-stalked, of a light purple colour; it is two-lipped, hypogynous and hermaphrodite. CALYX bilabiate, gamosepalous, with the upper lip circular and the lower one four-parted. COROLLA gamopetalous, somewhat horizontal, bilabiate, with the upper lip four-cleft, the lower one boat-shaped, entire, and curved downwards. STAMENS four, two short and two long, didynamous, bent down, lying in the boat-shaped lower lip of the corolla. GYNŒCIUM consisting of two carpels fused to form a superior syncarpous ovary, a single style, and a bifid stigma. The ovary is surrounded at the base by a ring-shaped disc which secretes honey; it is deeply four-lobed, the style springing from the base of the lobes (gynobasic, fig. 363). FRUIT consists of four separate achenes, really mericarps, (p. 145) lying in the cup-shaped persistent calyx; they look like small seeds and have a hard outer wall.

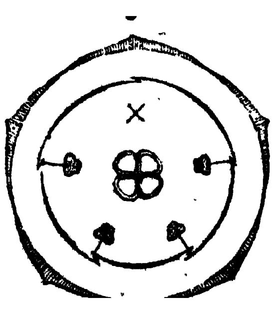


Fig. 364. Floral diagram of Labiatæ.

Fig. 365. Verticillaster of Labiatæ.

Other plants of the order are: the common weeds Hulkusha or Ghal-ghasa (*Leucas aspera*), Babui Toolsi (*Ocimum basilicum*), and several other species of Toolsi. The aromatic herb Podina, commonly used in making chutneys, is *Mentha arvensis.* Most Labiatæ plants are inhabitants of cool climates and are important for the fragrant oil which they yield. Oil of Lavendar is obtained from *Lavendula vera*; oil of Pipermint from *Mentha piperata.*

Very closely allied to the Labiatæ is the order **Verbenaceae**, the Teak family. It has irregular flowers but not in verticillasters, didynamous or diandrous stamens, 2-4 celled superior ovary and a terminal style. The Teak tree (*Tectona grandis*), well-known for its valuable timber, is a large forest tree with very large, deciduous, prominently-veined, opposite leaves. The flowers are small but clustered in large, white panicles which give a very delightful appearance to the plant when in flower (cold season). The flower is hexandrous and rather regular, a character not often shared by other verbinaceous plants. The calyx and corolla too have six segments or lobes. The ovary is four-lobed and grows under cover of an enlarged, bladdery, persistent calyx into a 4-celled drupe with a heavy coating of hairs. The commonest verbinaceous plant is the weed *Clerodendron infortunatum* mentioned on p. 130 for its characteristic pollination. Many plants of this order are small shrubs or herbs; various species of *Verbena* and *Lantana* are ornamental garden herbs. The common plant Nishinda (*Vitex nigando*) is a tall shrub with palmately compound (p. 61) grey leaves, covered with a silvery down all over, which are esteemed as febrifuge and antiseptic in Hindu medicine.

ACANTHACEAE (Bakash family).

Distinguishing characters:—Herbs and shrubs with simple, opposite, entire LEAVAS and irregular bilabiate gamopetalous flowers in bracteate spikes. The latter are very characteristic, for the bracts are often very prominent, and overlapping each other like the scales of fish hide the young flowers before they are fully opened.

CALYX, COROLLA and STAMENS as in Labiatæ.

OVARY superior, of 2 carpels, 2-celled with many ovules

attached to the placenta by long funicles. Style terminal, stigma 2-fid.

FRUIT a 2-valved capsule often brusting with a sudden jerk to scatter the seeds widely. (p. 159).

SEEDS attached to hard hooked supports, usually exalbuminous.

BAKASH (*Adhatoda Vasica*).

The plant is a perennial shrub well-known for its immense use as a medicine for cold and cough. The LEAVES are large, entire, exstipulate and lanceolate. The inflorescence is a bracteate spike. The FLOWERS are zygomorphic, hermaphrodite with five sepals which are slightly connate at the base; the petals also number five but form a bilabiate corolla by coalescence, the upper lip being composed of two petals and the lower one of three; the lobes remain twisted in the bud. The inner surface of the lower lip is marked with violet linings known as nectar-guides. The flowers are protandrous and *Pollination* is effected with the aid of bees. The lower part of the COROLLA is a tube the upper part of which splits up into two lips. The lower lip is broad and forms the conspicuous part of the flower; the upper lip is like a hood sheltering the bent didynamous stamens. Bees which pollinate these flowers sit on the lower lip, and as they push their body and tongue into the hollow of the corolla to reach the honey-secreting glands at the base of the ovary, the arching stamens come in contact with their back and load it with pollen-grains. The flowers are protandrous and consequently when the bee thus loaded visits an older flower, the bifid stigma also arching from under the hood of the upper lip, comes in contact with the pollen at the back of the insect and becomes pollinated (Bee flowers; See p. 125, figs. 220, 221). The fruit is a capsule.

The most common plants are the Kal-megh (*Andrographis paniculata*) used as a febrifuge and liver-tonic; Kule-khara (*Hygrophila Spinosa*) a spinous marshy herb very extensively used by Indian Kavirajis as a remedy for diarrhoea; several species of *Justicia* and *Ruellia* are ornamental garden herbs.

The order is very closely allied to *Labiatae*, but differs from the latter by a 2-celled unlobed ovary, terminal style, many-seeded capsular fruit and inflorescence in bracteate spikes.

AMARANTACEAE (Cock's-comb family).

Distinguishing characters.—Herbs with exstipulate, simple LEAVES.

FLOWERS minute, scaly, dry, condensed in spikes or heads, regular, hypogynous, hermaphrodite.

COROLLA absent, calyx scaly, coloured or scarious, persistent.

STAMENS five, free.

OVARY superior, one-celled, with one or more ovules.

FRUIT an utricle or a pyxis.

TYPE I. THE COCK'S-COMB (*Celosia cristata*).

The plant (fig. 149) is a hardy annual with alternate, simple, exstipulate LEAVES which vary in size and slightly in shape at different parts. FLOWERS arise at the terminal part of the main axis, or of the branches as well when present, in dense coloured spikes or heads which spread out flat like a cock's-comb (CÆNANTHIUM, p. 85). The minute flowers are subtended by glistening SCALY BRACTS. PERIANTH consists of five hard, membranous, white or coloured sepals. *There are no petals.* STAMENS five, opposite to the sepals, free for the most part except at the base where the five filaments are connected by a dry membranous tube. GYNŒCIUM consists of a single superior spherical ovary, a single central style, and a roundish capitate stigma. OVARY one-celled with 2 or more ovules, maturing into a thin, dry, shining pyxis (p. 143) which breaks up when ripe into two cup-shaped parts. SEEDS indefinite, minute, black, shining, smooth.

Type. II. NATYA-SHAK (*Amarantus*).

There are several kinds of the Natya-shak. The Kanta-natya (*Amarantus spinosus*) is an erect ramous annual with sharp thorns in the axils of the leaves. The cultivated Natya (*A. Blitum, var. oleracea*), the species most commonly used, has no thorns and differs also from the last in having three instead of five stamens. The Lalnatya (*A. gangeticus*) is like the last.

These annual HERBS differ from the Cock's-comb in being unisexual. The minute sessile FLOWERS form compact terminal spikes or axillary glomerules (p. 88). Each flower has a scaly bract and two lateral bracteoles. There is no corolla. Calyx consists of three small hard sepals, each terminating in a hard point in cultivated species, and of five sepals in the Kanta-natya. STAMENS five in the latter; and only three in the former. OVARY one-celled, with only one ovule. FRUIT an utricle with a single seed.

The order is not very well-defined as will appear from the above. The plants may, however, be at once recognised by the small, regular, scaly, hard flowers and coloured or otherwise shining calyx. The ovary is also distinctive, as well as the fruit, but the number of seeds varies very much.

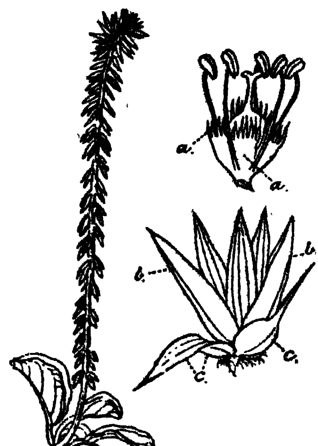


Fig. 366. The Apang; to the right the flower; C, bracts; B, calyx; A, stamens.

The Amarantaceæ are mostly weedy herbs or small shrubs. A very common weed of waste places is Apang, (*Achyranthes aspera* fig. 366). The fruits bend down and remain adpressed to the axis of the spike; they are easily

dispersed by roving animals, for they have fine stiff-pointed sepals surrounding them which become easily attached to the skin of animals.

URTICACEAE (Fig family).

Trees, shrubs, or herbs generally with hard rough simple leaves and milky juice. Flowers minute, imperfect monoecious or dioecious, often forming dense inflorescences. Ovary superior, one-celled with one ovule.

This large order is usually divided into three sub-orders :—

1. **Moraceae**, the Fig and Banyan family. Trees or shrubs with large stipules which fall off very early, and milky juice ; ovule pendulous.

2. **Cannabinaceae**, the Ganja family. Herbs without milky juice and persistent stipules ; ovule pendulous.

3. **Urticaceae**, the Bichui (Nettle) family. Herbs and shrubs without milky juice ; ovule erect.

MORACEAE.

This sub-order includes the various species of Figs and Banyans, as well as the Jack and the Mulberry trees which are easily distinguished by their milky latex and peculiar multiple fruits (p. 150). The leaves are rather rough, alternate and stipulate ; the stipules protect the young leaf-buds but fall off as soon as the bud unfolds (caducous). The inflorescence of Fig (fig. 150) is a hypanthodium (p. 89) ; likewise that of the Banyans. The flowers are unisexual and occur in the same inflorescence in the Fig and Banyans, in different spikes in the Jack. They are very minute. There is no corolla. The staminate flowers has only one or two stamens and four sepals. The pistillate flower has a tubular perianth, and an one-celled superior ovary containing but a single ovule with a bifid stigma. The ovary of the Fig and Banyans matures into a small hard seed-like achene ; of the Jack and Mulberry into a succulent berry. The fruits, however, all unite to form a multiple fruit.

The Fig plant is *Ficus glomerata ;* the Indian Banyan is *Ficus Bengalensis*, remarkable for the large number of adventitious prop-roots (p. 21, fig. 31) which its branches produce ; the Sacred Banyan (Aswatha, Pipul) is *Ficus religiosa.* The Jack tree is *Artocarpus integrifolia*, well-known for its huge nutritious fruits. The Mulberry tree, cultivated mainly for feeding silk-worms in sericulture, is *Morus indica.*

Of the sub-order **Urticaceae** the commonest plant is the Lal Bichuti (*Fleurya interrupta*), an erect annual weed with stinging hairs. The flowers are small and clustered in axillary or racemose cymes. The perianth consists of four green scales, free from the superior one-celled ovary.

Of the **Cannabinaceae** the Ganja plant (*Cannabis sativa*) is the most important. It is a small diœcious herb with palmatisect leaves

Fig. 367. *Ficus elastica*—The India-rubber plant.

and small greenish-white flowers. The dried female plants constitute ganja; charas so much smoked by the Chinese, is the resin exuding from the leaves, stems and flowers of the plant.

EUPHORBIACEAE. (Ricinus family.)

Distinguishing characters.—Trees, shrubs or herbs usually containing a milky or watery juice.

LEAVES usually simple, with small caducous or persistent stipules.

FLOWERS as a rule minute, unisexual, often surrounded by bracts, hypogynous.

COROLLA absent, CALYX present or absent, insignificant.

STAMENS various, from 1 to many.

CARPELS 3, united. OVARY 3-celled with 1 or 2 ovules in each cell. STIGMA of 3 bifid branches.

FRUIT a capsule breaking into 3 indehiscent cocci, sometimes cocci also dehiscing with force.

This is a very large tropical family of plants distinguished by their juice, small inconspicuous unisexual flowers and superior 3-celled fruit. The most common plant is the castor-oil plant (Bheranda or Rerhi—*Ricinus communis*) shown in fig. 368. This is a large tree-like herb with large alternate, peltate, palmately-lobed simple leaves (1) and terminal panicles of unisexual flowers. The male or staminate flowers are on the lower part of the inflorescence, the female flowers are at the top (2). Each male flower contains 5 sepals and a copiously branched cluster of stamens (5). The female flower (3) contains the 3-celled ovary with 3 large bifid stigma. The structure of the stamen and the stigma shows that the flowers are wind-pollinated. Each cell of the ovary contains a single ovule (4). The fruit is a capsule dehiscing with explosion so that the seed is scattered to a great distance.

Other common plants are.—The Lal Bharenda (*Jatropha gossypifolia*) and the Bag-Bharenda (*Jatropha curcus*) are common road-side plants. The Coral plant (*Jatropha multifida*) is a garden plant with dichotomously branched cymes of small red flowers. The Tri-shir Monsa (*Euphorbia antiquorum*) is a common hedge plant with succulent leafless thick 3-angled stem armed with spines. The Monsa or Monsa-shij (*Euphorbia nerifolia*), sacred to the goddess Monsa, is another fleshy plant with thick fleshy leaves. Lal-pata (*Euphorbia pulcherrima*) is another favourite garden plant with a circle of vermillion-coloured bract-leaves at the end of the twigs. The Crotons of the Gardens so much prized for their coloured variegated leaves are species of *Codiæum variegatum*. The hedge-plant Rang-chitra is *Pedilanthus tithymaloides*. The Lal-Bhichuti (*Tragia involucrata*) is a small twining or trailing herb covered all over with stinging hairs which give a very painful sensation when rubbed over the skin.

The order abounds in many economic plants of the highest impor-

tance. The India Rubber Trees (*Hevea Brasiliensis* and *Manihot Glaziovii*) are much cultivated for their yield of Rubber which is obtained from the milky juice flowing from incisions made in the bark. There are

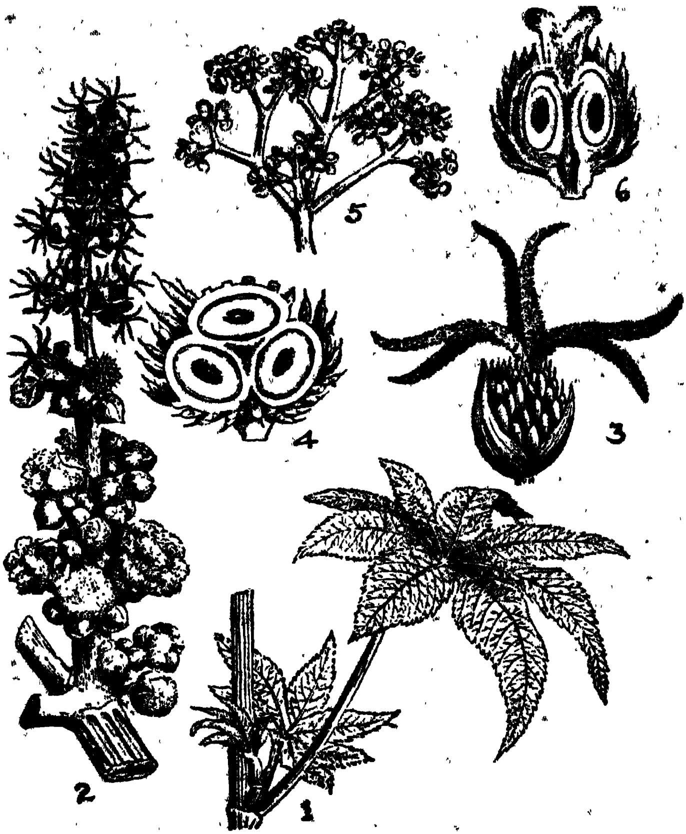


Fig. 368. The Castor-oil plant.

many plants of medicinal value, such as the Mukta-jhuri or Swet-Basanta (*Acalypha indica*) and the Khirui (*Euphorbia thymifolia*) of which there are different varieties.

CHAPTER XXX.

MONOCOTYLEDONS.

GRAMINACEAE—(Grass family).

Distinguishing characters.—HERBS (except the Bamboo) with jointed cylindrical stem, hollow internodes and alternate ligulate sheathing LEAVES.

FLOWERS in spikelets with scaly glumes, very imperfect, inconspicuous, anemophilous.

STAMENS usually three (or in some cases six) with large versatile anthers.

OVARY superior, one-celled, with a solitary ovule and crowned with two long feathery styles.

FRUIT a dry caryopsis with abundant starchy albumen.

TYPE I. THE RICE PLANT (*Oryza sativa*).

The **plant** is a herb with a slender erect stem, solid at the nodes and hollow in the internodes (culm, p. 34), which produces numerous fibrous roots from the lower nodes. LEAVES solitary at each node which they encircle by their sheathing base split on one side, distichous (p. 72), simple. The blade is linear with parallel venation; between the blade and the sheath is a membranous appendage, termed the LIGULE (p. 52) which prevents rain-water from running into the sheath and rotting the tender nodes. The epidermis is silicated and hence the blade gives a sharp cut when sharply drawn through the fingers.

Flowers arise in panicles. The lateral branches of the inflorescence are one-flowered spikelets (fig. 371). Each spikelet has two minute outer bracts (G) subtending it and two large inner bracts, called PALEÆ (p_1, p_2) one of which is provided with an AWN (a). Enclosed by these

scaly bracts is the very much reduced flower. The perianth leaves are represented by two minute fleshy scales called

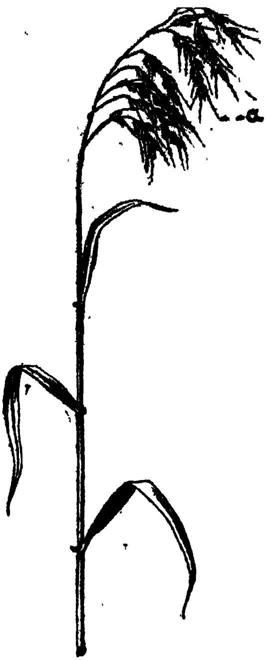


Fig. 369. The Rice plant.

Fig. 370. Spikelet of Graminaceæ (diagrammatic); g, glumes: P_1 P_2 the paleæ; s, stigma; l, lodicules, a, anthers.

LODICULES. STAMENS six with slender filaments and large linear versatile anthers (A). GYNŒCIUM consists of but a single carpel standing opposite the paleæ. The OVARY is superior, rounded, small, one-celled and contains but a single campylotropous ovule. There are two much branched FEATHERY STYLES. The FRUIT is the well-known grain; the husks are the bracts, and the inner grain is the fruit (CARYOPSIS). The pericarp is thin and adherent to the still

thinner testa within which lies a starchy endosperm (pp. 144, 155). Embryo small, occupies a lateral position in the albumen.

The bracts serve to protect the flower. The lodicules, which really represent the perianth, stretch out on a sunny day and force open the paleæ. The anthers then come out, discharge their pollen to be carried by the wind, and then fall away. After pollination (anemophilous, see fig. 222, p. 126) the lodicules shrink back, the bracts close again and protect the ripening ovary.

Type II. THE WHEAT (*Triticum vulgare*).

The plant has very much the same vegetative characters as the last. The FLOWERS, however, are arranged in short, sessile, spikelets which are disposed racemosely on the main axis of the inflorescence making it a compound

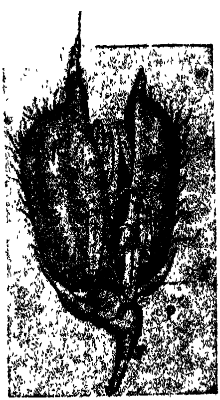


Fig. 371. Flower of Rice P_1 P_2 paleæ; G, glumes; A, anthers.

Fig. 372. Parts of the flower of wheat; G. glumes, P, paleæ L, lodicules; S, stamens; O, ovary with styles.

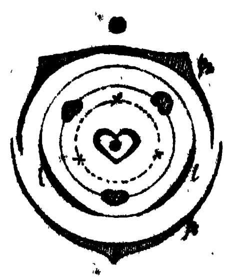


Fig. 373. Floral diagram of Grass. P_1 P_2 the outer and inner paleæ; l, lodicules. The inner whorl of stamens is not present.

spike. Each spikelet is subtended by a pair of hard dry scales, the glumes, and bears three or four flowers (fig. 370).

Each flower (fig. 372) has a pair of paleæ of which the inner is called the FLOWERING PALEA; it often terminates in a sharp awn. The two minute lodicules (L) are inserted just below the ovary. There are THREE STAMENS with their large versatile anthers. Gynœcium as in the last case.

The plants of this order have branched trailing or rhizomous stems which are commonly solid. The Bamboos, for instance, have very hard, woody, knotted, underground stem which is solid all through. Only the smooth, cylindrical aerial branches have swollen solid nodes and hollow internodes. In the sugar-cane and Maize the whole stem is uniformly solid. The aerial and underground branches arise from the leaf-sheaths which they split open and grow up into flower-bearing branches. The Grasses are copiously branched, annual or perennial, trailing or prostrate plants which form small tufts or mat-like layers.

The inflorescence which is very peculiar and distinctive of the order is a compound or paniculate spike. Each spikelet (fig. 370) contains a few flowers each of which arises from the axil of a hard and rough scaly bract termed PALEA. This flowering or fertile palea (p_1) is more or less boat-shaped and has its midrib drawn out into a long, pointed, sharp bristle termed the AWN. Nearer the flower, above this outer palea and enclosed by it, is another scale-like bract called the INNER PALEA (p_2). The small spike itself is subtended by two smaller non-flowering or sterile bracts called GLUMES (*g*). They are armed with short hard bristles. The glumes serve to fasten the spikelets of fruits to the body of grazing animals and thus help dispersion. When the fruit falls on a soft soil the glumes stick fast to it and the long awn drives the grain into the earth. The awn is very hygroscopic and executes peculiar twisting movements as it absorbs moisture in wet weather or dries up on a hot day.

In most cases the spikelet consists of two, three or five flowers, and then its axis (called RACHILLA) is jointed and breaks up into short and crisp articulations above each fruit.

The flower in this order is generally hermaphrodite, sometimes unisexual (Maize), hypogynous, and greatly reduced. There is no perianth but only two small globular scales or lodicules to represent it. The purpose of the perianth is served by the paleae. The lodicules help to open the dry scaly perianth when it is time for pollination. The flowers are generally triandrous, but the Rice plant and the Bamboo are hexandrous. The large linear anthers dangle in air and burst when warmed by the sun, so that the discharged pollen is wafted away by even the gentlest breeze. The large feathery stigmas and styles catch the pollen-grains as they float away in the wind. The ovary is composed of one carpel and bears two large feathery stigmas. In the Maize there is only one long style ; the female flowers form a dense spike with styles drawn out into long filaments which together form a silky tassel hanging from the top of the spike. In some Bamboos there are three instead of the normal two styles.

The fruit is the well-known grain caryopsis (p. 144). It is full of starch. All the cereals, Rice (*Oryza sativa*), Maize (*Zea mays*), Wheat (*Triticum vulgare*), Barley (Job—*Hordeum hexastichum*), Oats (Jai—*Avena sativa*) etc., afford valuable food for the abundant starch their grains contain.

The Sugar-cane plant (*saccharum officinarum*) is well-known for its sweet and juicy culm which is very rich in saccharine matter. It is a tall perennial with a tuft of leaves at the top, the lower leaves being easily shed. In cultivation it is rarely allowed to flower. The terminal part is lopped off before the flowering time, for by this means the yield of sugar is increased. The plant is readily propagated by cuttings.

The Bamboos belong to the genus *Bambusa*. They are a tribe of gigantic tropical grasses. The flowers differ from the grasses in having six stamens and three lodicules.

Of the comon meadow grasses the most common and well-known is the Durba (*Cynodon dactylon*) used in Hindu worship. *Chloris barbata* is another very common weed. It has a peculiar inflorescence. Four or five spikes spread out umbrella-fashion from the apex of a scape; when young they form a vertical cylinder. Each spike contains numerous awned flowers on the lower side. Some of the grasses are aromatic herbs and for this reason are highly prized as pot plants. The Lemon-grass and the Khus-khus belong to the genus *Andropogon*. The common field-weed Chor-kanta is *Andropogon aciculatus*. The Koosh grass is *Poa cynosuroides*, while the reed Naul is *Phragmitis karka*.

CYPERACEÆ (The Sedge family).

These are grass like shrubs with sympodial rhizome from which subærial stems are sent off. The stem is triangular and do not possess the swollen nodes nor the hollow internodes characteristic of Graminaceae. It differs from the latter in having closed tubular leaf-sheaths, no ligules, spiked, perfect or unisexual flowers one in the axil of each of the glumaceous imbricated bracts destitute of any envelopes, or with a tubular bract, or with hypogypous bristles or scales in its place. They are usually monoecious and hermaphrodite. The stamens are hypogynous and are usually three in number of which one is anterior and two posterior. The anthers are basifixed, bilocular and introrse. The pistil is typically trimerous. There is a single style branched at the apex and bearing two or three stigmas. The ovary is free, one-celled and one ovuled—the ovule being anatropous. The fruit is a kind of nut.

As regards *pollination* the flowers come under the anemophilous family—cross-pollination being favoured by protogymy (see p. 122; Fig. 222). The most common plants are Mootha (*Cyperus rotundas*) and Madur Kati (*Cyperus tegetum*) the stems of which are used in the manufacture of mats.

LILIACEAE (The lily family).

Distinctive features :—1. (The plants are generally herbs or shrubs, with fibrous roots or a bulb or corm. *Leaves* large, often succulent, cauline and radical.)

2. *Flowers*: hermaphrodite, collected in an inflorescence of the racemose type; solitary flowers are also met with; the flowers are

actinomorphic and save a few species are trimerous with two petaloid perianth whorls. The bracts are small, scarious or spathe-like.

(*a*) *Stamens* :—free, hypogynous ; in two whorls of three each.

(*b*) *Carpels* 3, connate in a superior 3-celled ovary with 2 or more ovules in each cell.

3. *Fruit* a capsule with loculicidal dehiscence ; the seeds are albuminous :

PIANJ (*Allium Cepa*).

The stem is found in the form of an underground bulb from the lower surface of which are given off innumerable fibrous roots. The bulb is composed of a number of concentric overlapping leaves or scales standing on a compact mass. From this compact mass within a scape is sent forth into the air terminating in a cluster of flowers subtended by a scarious bract. (Fig. 41). The inflorescence is umbellate and more or less bracteate. The flowers are regular, pedicellate, hermaphrodite and complete ; the perianth consists of two petaloid whorls, the stamens as well are arranged in 2 whorls of 3 each alternating with 3 carpels. The ovary is superior, trilocular, each containing many ovules whose placentation is axile. The resulting fruit is a capsule. The propagation of the plant, however, does not depend upon the germination of the seeds but takes place in the process as follows. The bulb becomes soft and shrinks with the growth of the plant and by the time its contents are used up several new buds arise in the axils of the dead scale-leaves ; under satisfactory conditions of environment these grow up into independent plants. Thus is it commonly propagated.

The most common plants are the Garlic or Rasun (*Allium sativum*) and *Allium tuberosum*, cultivated for their edible bulbs ; Ulatchandal (*Gloriosa superba*) which climbs by tendrils terminating leaf-blades (see Fig. 103) ; and Satamuli (*Asparagus racemosus*) which has fasicles of fusiform roots (fig. 34).

AMARYLLIDACEAE. (The Amaryllis family).

The distinguishing characters of this order are the same as those of Liliaceae. It differs from the latter only in having an inferior ovary.

RAJANI-GANDHA (*Polyanthes tuberosa*).

The plant is cultivated in our gardens for its sweet-smelling beautiful flowers. The stem is a short underground bulb from the upper surface of which arise large fleshy scale-leaves over-lapping each other

(See p. 63). The plant on attaining maturity sends forth the scape into the air on which develop innumerable flowers tubular in shape. The structure of the flowers is very much like those of Liliaceae except that its ovary is inferior. The plant is not largely propagated by means of the seeds. This is done mostly by the process described under Liliaceae.

Plants under this order have got much economic value. Several are commonly characterised by being emetic, purgative and poisonous. The *Agaves* are exceedingly valuable plants having abundant innocuous saccharine sap and large leaves containing excellent fibres. In the Rajani-gandha (*Polyanthes tuberosa*) a garden plant, flowers are on the scape which comes out from the under-ground stem in the rainy season. The Sukha-darshan-lily (*Crinum latifolium*) is a common garden herb with flowers streaked with red nectar-guides for securing pollination.

SCITAMINEAE.—(Banana family).

Distinguishing characters.—Perennial herbs with large pinnately-veined LEAVES and large flowers.

FLOWERS epigynous, hermaphrodite, zygomorphic or asymmetrical.

STAMENS greatly reduced, often petaloid.

OVARY inferior, three-celled, with many ovules on axile placenta.

This large order is usually divided into three well-defined sub-orders which differ mainly in the number of stamens present.

	MUSACEAE (BANANA FAMILY)	CANNACEAE (CANNA FAMILY)	ZINGIBERACEAE (GINGER FAMILY)
Plants......	Tree-like herbs	Smaller herbs.	
Flowers......	In large cone-like spathaceous spike.	In simpler spikes.	
	Zygomorphic	Asymmetrical	Zygomorphic.
Stamens...	5 perfect	Only 1 perfect and the rest petaloid staminodes.	
		Only 1 anther-lobe, perfect, the other half expanded and petaloid.	Both anther-lobes perfect, style running between them.

MUSACEAE

THE BANANA (*Musa paradisiaca*).

The plant is a very large tree-like herb with an under-ground rhisomous stem. The aerial shoot which appears to form the trunk of the tree is not really the stem but the leaf-bases tightly rolled up. In a very young plant there is no aerial stem at all, but about flowering time a white solid column may be witnessed in the centre of the false trunk; this is the stem. It is really a scape (p. 31) which pushes its way through the leaves, and, at the proper time, comes out of the cluster of foliage bearing the characteristic conical inflorescence, the 'Banana flower.'

Fig. 374.

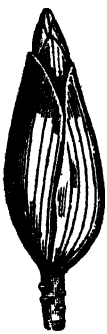


Fig. 375.

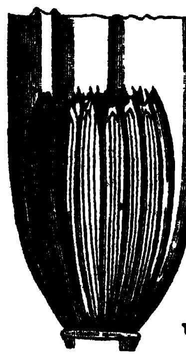


Fig. 376.

Fig. 374. The flower-cone of Banana.
Fig. 375. A spathe of same with its axillary row of flowers.
Fig. 376. A single flower; uo, the inferior ovary.

The LEAVES are very large with a very stout midrib from which the smaller veins run to the margin at right angles. Resistance to the wind is overcome by the lamina being split up into numerous thin parts, which make the leaf look and act like a pinnate leaf. The base of the leaf goes to form the trunk; it is very long, boat-shaped and spongy in texture, being provided with very large air-cavities.

Flowers arise in dense spicate clusters (spadix. p. 84) which form the well-known flower-cone. They are arranged in two rows in the axils of large, boat-shaped, leathery bracts called *spathes*, crimson and smooth on

the inside and dull and grooved on the outside. The spathes open gradually from the base to the apex, but fall off soon after fertilisation. In a young inflorescence they overlap and partially enclose each other.

The *perianth* is a five-toothed irregular tube with a slit running down its side (fig. 376). Before this slit stands another free petal. The tubular perianth is really composed of three petaloid sepals and only two out of three petals, the third petal being the free one. *Stamens* only five, standing before the five teeth of the perianth-tube; the sixth stamen is abortive. Flowers which open first, those which lie towards the base of the spike, contain sterile stamens but have fertile pistils which produce the fruits. Those occupying the middle portion of the spike are in function and structure hermaphrodite; while those which lie towards the apex have their stamens only fertile, the pistils being sterile. Hence fruits are produced only at the base and the middle portion of the spike, the bracts and flowers at the apex falling off without fructifying. *Ovary* inferior, three-celled, with numerous ovules attached to an axile placenta. Style simple, stigma six-lobed. *Fruit* is an oblong berry.

Pollination takes place with the help of bees and other insects. Honey is secreted at the base of the flowers which are rendered attractive by the scarlet colour of the hood-like spathes. The six-lobed stigma is glutinous and pollen easily adheres to the stigmatic lobes. Inter-crossing is secured by the gradual opening of the bracts and their axillary flowers, and also by the contrivance of developing sterile stamens in the hermaphrodite flowers.

With the production of the fruit the growth of the plant ends. It then gradually withers and fresh plants are produced from buds on the underground stem. The seeds are not properly developed in those Bananas which are the more esteemed. This is due to artificial selective cultivation. Wild plantains, however, produce seeds as usual.

CANNACEÆ

The **Canna** (Sarbajaya) is a garden annual cultivated for its beautiful variegated flowers. It is a small herb with an underground rhizomous stem and comparatively large, petiolate, prominently-veined leaves. Flowers are arranged in pairs on a long spike. The flower is asymmetrical (fig. 377). The *calyx* is composed of three small coloured sepals. The *corolla* is represented by three narrow petals which stand outside the inner large petal-like conspicuously coloured leaves. These are the petaloid stamens the anthers of which do not develop. One of these

staminodes, as they are called, has an one-celled anther half way down its edge, the other anther is transformed into the flat petal-like structure. Just in front of this fertile stamen is a curved highly coloured and streaked staminode called the *labellum* (fig. 377). The style and stigma are represented by a narrow short flattened structure. The ovary is inferior being marked on the outside by small spinous process. It is three-celled and contains numerous ovules in each cell. The fruit is a capsule bursting into three valves.

To the **Zingiberaceae** belong the Ginger plant (*Zingiber officinale*), Turmeric (Huldi—*Curcuma longa*), Cardamon (Elachi—*Elettaria Cardamomum*) and several other spices, as well as a few attractive pot herbs chief of which are the Bhoi-champa (Bhumi-champaka—*Kaempferia rotunda*) and the Dolon champa (Hansraj—*Hedychium coronarium*).

The ginger plant is a small herb with a creeping jointed

Fig. 377. Flower of Canna; C, C, the three large staminodes; g, the labellum, above it is the fertile stamen which is partly expanded; F, the corolla; d, the calyx; e, the inferior ovary.

fleshy rhizome which constitutes the ginger of commerce, large herbaceous leaves, and spicate flowers borne on long scapes. The perianth is tubular, six lobed, and surrounds six staminodial filaments which represent the stamens. There is but one fertile stamen with its 2 anthers

leaving a groove in the middle through which runs a filiform style ending in a funnel-shaped stigma and an inferior 3-locular ovary with numerous ovules. Opposite the stamen there is a large petal-like lip, violet in colour, known as the *labellum.*

The Bhoi-champ (*Kæmpferia rotunda*) is an elegant plant highly prized for the beauty and fragrance of its flowers. It is a small stemless herb with attractive rosettes of large radical leaves, and very short scapes bearing from four to six sessile flowers. The flower is large, pure white, deliciously fragrant, obliquely funnel-shaped, variously coloured in the inside. There are several staminodial filaments on one of which there is a liner anther. The stigma is peculiarly funnel-shaped and is borne upon a filiform style. Both this plant and the Dolurchampa (Hansa-raj—*Hedychium coronarium*) flower before or during the rains. The latter plant has unlike the above an erect stem and sessile lanceolate leaves in two ranks on opposite sides of the stem. The large, pure white, strongly fragrant flowers have long slender tube and an expanding three-parted border, obliquely irregular. There are two short fleshy nectarial staminodes at the base of the slender style which terminates in a large hairy perforated, glandular stigma. It constitutes one of the most charming indoor pot plants during the rainy season.

PALMACEAE (Palm family).

Distinguishing characters.—Trees or woody climbers with unbranched stem (CAUDEX).

LEAVES very large, pinnately or palmately divided.

FLOWERS regular, small, trimerous, hypogynous, aggregated in profusely branched inflorescences, with several large boat-shaped spathes.

STAMENS six. OVARY superior, usually three-celled.

FRUIT a drupe with a tough fibrous pericarp.

The Palms of which the most common are the Cocoanut Palm (*Cocos nucifera*), the Palmyra Palm (Toddy Palm—*Borassus flabelliformis*), the Betel-nut Palm (*Areca catechu*) and the Date Palm (*Phœnix dactylifera*) are characterised by their long slender unbranched stem and huge massive leaves forming a crown at the top. The surface of the stem is marked with horizontal scars left by the fallen leaves, the older and lower scars appearing to encircle the whole stem. There is only a single terminal bud which continues the growth and if this is destroyed, by lightning, say, the whole plant dies. The LEAVES are the largest in the vegetable kingdom; they have a large pinnately or

palmately divided lamina and a massive channelled petiole with a large sheathing base. The INFLORESCENCE is generally axillary and hangs down from the axil of leaves. It consists of large branched spikes studded with inumerable small flowers protected by large boat-shaped membranous spathes. In some cases, as in the Talipot or Fan Palm (*Corypha unbraculifera*) the inflorescence is terminal, coming out from the terminal or apical bud when the plant is some twenty or twenty-five years of age, and then the plant dies after flowering and fruiting. The number of flowers in an inflorescence is some times surpassingly large; the Date Palm, it is said, may bear 12,000 flowers at a time and in certain Brazilian Palms the number is computed to be somewhere near 600,000 in one plant!

The **flowers** are small, greenish or yellowish in colour and often though not always unisexual. The *perianth* consists typically of six dry segments, hypogynous, and regular. Both the male and female flowers lie on the same plant, but the Palmyra Palm is diœcious. ***Stamens*** generally six. The *gynœcium* consists of three carpels fused to form a superior syncarpous, three-celled ovary with a single ovule in each cell. The fruit of the Palmyra (Tal) has three large stones. In other Palms, however, two out of the three cells are abortive and only one cell with a single ovule matures into a fibrous drupe. The fruit varies very widely. That of the Cocoa-nut, the Betel-nut, and many other Palms is a fibrous drupe (p. 147). The Date fruit is like a berry (p. 147). The typical tri-carpellary character is preserved in the fruit of the Palmyra Palm. The seed is albuminous, containing a minute embryo embedded in a copious oily endosperm.

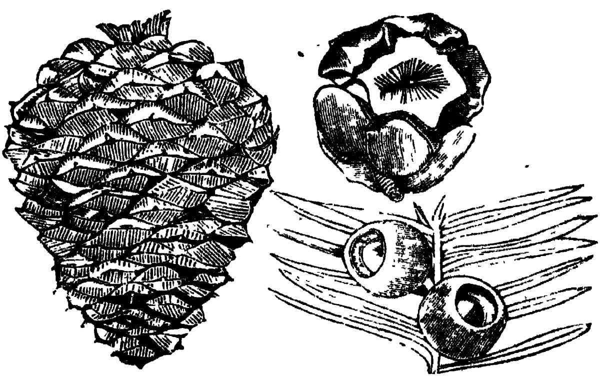
Other plants are.—1. The Sago Palm (*Caryota urens*), indigenous to the Malabar coast, has the largest leaves of all Palms. Sago is a kind of starchy matter stored in the soft parenchyma of the stem. 2. The Cane Palms (*Calamus rotang*) are elegant climbers which cling to supports by means of hooked prickles or long spreading leaves which permit the plant to grow to enormous lengths, running right up to the tree-tops of dense forests they grow in. The *cane* is very smooth on account of the exudation of wax and mineral matters, chiefly silica, and is largely used in the manufacture of useful articles of furniture.

CHAPTER XXXI.

GYMNOSPERMIA.

The **Gymnosperms** differ from the Angiosperms in having their seeds exposed or naked; they are naked-seeded plants. The carpel of the Angiosperms forms a closed cavity, called the ovary, within which the ovules develop. The carpel of the Gymnosperm is often greatly reduced and scaly and is never closed, so that the ovules are exposed. A fruit-case or pericarp, consequently, is wanting in the Gymnosperms.

Fig. 378. Fig. 379.



Gymospermous fruits.

Fig. 378. Pine Cone. Fig. 379. Top—a globular cone; bottom—single ovules enveloped in an aril during ripening, so that they look like a berry.

The **flowers** are extremly reduced, and are all unisexual and generally monœcious. The carpels alone form the female flower and the stamens alone the male. Floral envelopes are, as a rule, absent. They are all wind-pollinated. The pollen-grains are produced in large numbers in two or

more chambers at the *base of the scaly staminal leaf.* They are spherical and have often two wings or air-sacs which make them extremely light and thus help their dispersion by the wind.

The female flowers form the characteristic cone. It consists of an elongated axis on which the carpel-leaves are spirally arranged. In the Pines, the most important class of Gymnosperms, each scaly carpel bears two ovules at the base; they mature into winged seeds which are dispersed by the wind.

Fertilisation in **Gymnosperms** differs from that in Angiosperms (p. 318). As there is no ovary and stigma the pollen-grains germinate directly on the micropyle of the ovule. While the pollen-grains are being shed, the scales of the female cone (fig. 378) separate slightly and the mouth of the ovules becomes sticky. As the wind blows the pollen-grains over the female cone, they readily adhere to the micropyle and then germinate. The outer wall of a germinating pollen is ruptured and a short pollen-tube is produced. This is composed of a few cells, from 2 to 4, of which one is the large cell of the pollen tube in which floats another cell called the **antheridial mother-cell.** This later on divides into two male sexual cells called the **generative cells.** The generative cells are walled cells, not naked like the generative nuclei of Angiosperms (cf. p. 318). The ovule has a nucellus and single coat. Inside the ovule a single large cell, called the embryo-sac, is first formed as in the Angiosperm. This becomes gradually filled up by a multicellular tissue by the repeated division of its nucleus and protoplasm. This tissue is the **endosperm**; it contains nutritive substances for the nourishment of the young embryo, and grows at the expense of the tissue of the nucellus outside the enlarged embryo-sac. At the top or the mycropylar end of this tissue (endosperm) are formed

generally two archegonia, each consisting of a large *ovum* and a short neck of several small cells. The archegonium corresponds to the Egg-apparatus of the Angiosperm. The ovum is the female sexual cell, and instead of the 2 synergidae cells, a row of neck-cells is formed. Fertilisation takes place by the fusion of one generative cell of the pollen-tube with the ovum after the pollen-tube has pierced the tissue of the nucellus and penetrated through the neck-cells of the archegonium. The phenomenon of the pollen-tube moving towards the ovum is an instance of *chemotropism* (p. 324). The fertilised ovum then rapidly forms the suspensor, the pro-embryo and finally the embryo (cf. p. 320). The number of cotyledons varies from 2 to 7.

The endosperm of the seed is the nutritive tissue storing food matter for the embryo. It is formed *before fertilisation, not after*, as in *Angiosperms.*

CONIFERAE.

The most important natural order of the Gymnosperms is the Coniferæ or the Pine family, so called from its peculiar cone-like "*fruit.*" Like most Dicots the Coniferæ are large, much-branched trees with the stem and root growing continually in thickness. The bundles are open and arranged in a ring as in Dicots. The xylem or wood, however, consists entirely of large bordered pitted tracheides, true vessels are not formed; neither are companion-cells formed along with sieve-tubes of the phloem. The plants are highly resinous, the resin being collected in long resin-ducts. Turpentine is produced from the resin which easily flows from wounds reaching the wood. The plants are natives of hilly tracts but some are cultivated in gardens on account of their tall, conical, graceful form (*Araucaria*) and the evergreen foliage (p. 68).

The Pine (*Pinus longifolia*) is a tall tree with whorled

branches forming a beautiful rounded head of light green foliage at the top. The common Khasia Pine or Saral-gach of the garden is *Pinus Khasya.* The leaves and branches are of two forms: (1) the *long shoots* which form the branches have small scale-leaves from the axils of which arise (2) the *dwarf shoots* or smaller branches in whorls, bearing the long needle-like leaves (fig. 131, p. 75). The dwarf shoots are arrested branchlets consisting of a very short axis covered with brown membranous sheathing scales which surround 2, 3, or 5 green leaves (3 in *P. longifolia*). The male flowers form deciduous catkins (fig. 380). The female flowers or cones are formed on separate branches. The cone or fruit (so called) is formed of the enlarged woody carpels which are spirally arranged on the axis and are more or less thickened at the apex. Seeds two at the base of each carpel-scale, flat, with a large wing at one end which helps their dispersion by wind.

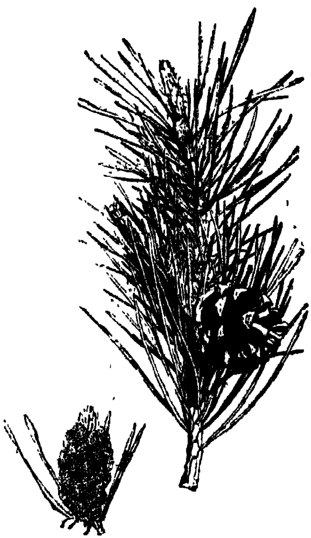


Fig. 380. To the right a shoot of Pine showing the acicular leaves and a female cone. To the left a male flower containing numerous anthers.

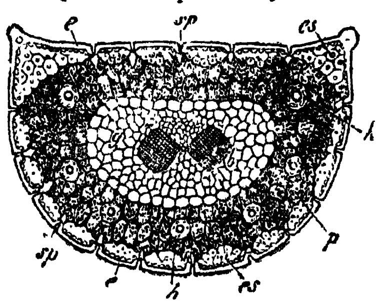


Fig. 381. Transverse section of Pine leaf. e, thickened epidermis with cuticle; es, sclerenchyma; sp, stomata; h, resin passages; g b, the stele enclosing two vascular bundles. The dark zone is the chlorophyllous parenchyma of the mesophyll.

CHAPTER XXXII.

PTERIDOPHYTA

The *Pteridophytes* are the most highly developed Cryptogams. They are called *Vascular Cryptogams* because they possess vascular tissue or bundles like the higher plants, but not true vessels (p. 211). Their xylem is composed of tracheides and wood-cells alone. They produce true roots like the Phanerogams and their leaves also correspond in structure with those of Phanerogams, having a mesophyll and vascular bundles.

The difference from higher plants lies in the fact that flowers and seeds are not produced in Pteridophytes. Multiplication takes place by unicellular spores which are formed in special chambers called *sporangia* originating from the leaves. The spore-producing leaves are called *sporophylls*. The spores are formed in enormous quantities, are dispersed by the wind, germinate on reaching a moist cool place, and in this way the plants multiply very rapidly. The most common and wide-spread amongst the Pteridophytes is the **Ferns.**

The Ferns exhibit a wide range of forms, varying in size from the small herbaceous annuals commonly used as pot-herbs to gigantic Tree-Ferns 30 to 40 ft. in height which are common in Ceylon and in the hills. They have usually a simple or branched creeping rhizome trailing above or below the ground; aerial woody stems appear only in the larger sorts, particularly in the Tree-Ferns. The stem dies off continually at the lower end or becomes lignified and functionless. The rhizome is very stunted in form and is beset with a large number of brownish-black scales, termed *ramenta*. They serve to keep the rhizome moist by absorbing moisture.

A general characteristic of Ferns is the large size of their leaves which are often highly compound (fig. 382). Fern leaves are commonly known as *fronds*. They are rolled up when young in a circinnate fashion (p. 68); the lower part of the petiole is furnished like the stem with the ramenta. The older leaves dry up or rot away when they attain maturity. Unlike the leaves of flowering plants those of the Ferns have a long-continued apical growth, and hence are sometimes very long. They are very commonly provided with long petioles which appear

Fig. 382. *Polypodium*. The younger leaf-buds at the bottom are coiled like a dog's tail. The large leaf shows the spores on the lower surface $(\times\frac{1}{8})$

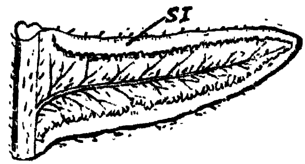


Fig. 383. Leaf of *Pteris*. SI, the margin of the leaf infolded to form the false indusium $(\times\frac{1}{8})$

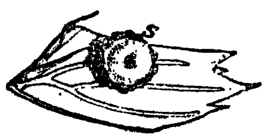


Fig. 384. Part of a leaf of *Aspidium*. S, a sorus covered by a thin indusium.

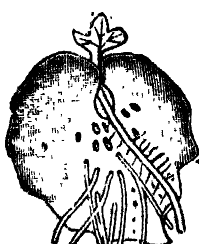


Fig. 385. Prothallium of Fern with rhizoids and a young Fern plant developed from an embryo ($\times 10$).

to spring in clusters from below the ground, but virtually from the underground rhizome. The leaf-lamina may be simple and entire but is usually broken up pinnately into many lobes or segments, or is pinnately compound. The upper leaf-segments are usually connected with spore-production, the lower ones having a strictly vegetative function. The *roots* arise in clusters from the underground stem and are strictly adventitious in origin, sometimes they break out from the lower part of the erect aerial stem like the roots of Palms.

On the lower surface of the leaf brown or black lines or spots are noticed (fig. 382). These are the places where

Fig. 386. The Maiden-hair Fern—*Adiantum caudatum*. At the upper part a leaflet showing the lower surface with the spores (S) and indusium (L).

spores are formed in certain special sacs called sporangia. The spores are asexual reproductive bodies which fall away

from the plant, are dispersed by the wind, and then coming to a moist place germinate to produce a thin plate of green leaf-like body, called the prothallus or prothallium. A prothallium (fig. 385) when fully developed produces sexual cells which by uniting give rise to the fertilised ovum of the daughter plant.

The Maiden-hair Fern (*Adiantum caudatum*, fig. 386), a very common Fern growing everywhere on ruins of wall or in the crevices of moist rocks, may be taken as the type. The stem is a small creeping rhizome which nestles in creeks and crevices where there is moisture. The leaves arise in clusters. The petioles are long, very slender, brownish black, shiny and remain more or less hidden from view by the luxuriant abundance of light green foliage developed on them. The leaf is compound, leaflets small. The margin of the mature leaflets are slightly folded on the under surface (fig. 386, *l*) under cover of which are developed the sporangia in groups called *sori*. The margin by thus bending over serves to protect the *sorus* and is termed a *false indusium*. The true indusium is a very thin membranous tissue which spreads over and protects a sorus in certain other Ferns, as in *Aspidium* (fig. 384. s), The sporangium (fig. 387) is a stalked capsular body with a short slender stem and a terminal swollen body, like a biconvex lens,—this is the capsule or the spore-sac. The capsule has a ring of marginal cells, strongly thickened and lignified, which appears brown or yellow and brings about its rupture when the atmosphere is dry. This can be seen very neatly if we heat a slide containing the sporangia, and mount it quickly for observation. The strong thickened yellowish ring appears to recoil and to straighten, scattering the spores by this means. The ring is termed the *annulus* and is variously formed in the different species of Ferns. The tissue of the leaf from which the sporangia originate is like a soft cushion and forms the *receptacle* or the *placenta* (fig. 388, P).

In the *Polypodium* (fig. 382) the indusium is very distinct and extends as a large but thin outgrowth of the leaf. The sori also are clustered in patches, not in a line as in the *Adiantum*. In *Pteris*, a genus of Ferns very common in this country, the linear leaflets have their margins folded back as in the *Adiantum* but here the whole leaf-margin is thus involved and the sporangiferous tissue is a continuous line (fig. 383.)

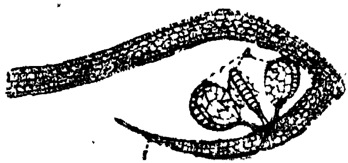


Fig. 387. Section of leaf of the Maiden-hair Fern showing the infolded margin forming the false indusium (I) and enclosing a sorus of sporangia ; o, the annulus.

The **sporangia** are developed from single epidermal cells some of which are sometimes (as in *Pteris*) not modified but left in the form of slender hairs. These are termed PARAPHYSES. A sporangium has very generally a wall composed of but a single layer of cells. In a few cases, however, the sporangia develop from a group of leaf-cells, both epidermal and sub-epidermal, and are consequently of a rather hard texture. Such sporangia have no annulus. The commoner Ferns are said to be LEPTOSPORANGIATE on account of the trichomous nature of the sporangia, while others where the sporangia are composed of many leaf-cells are said to be EUSPORANGIATE.

The **spores** have a cutinised outer wall which resists strongly the injurious action of moisture or heat. Hence they retain their germinating power for a long time. On germination the hard outer wall bursts ; the cell then divides, and by repeated division a flat multicellular structure or the prothallium is formed (fig. 385). The prothallium is a flat green heart-shaped thallus. It produces from the lower surface numerous brown filamentous hair-like structures, called *rhizoids*, which sink in the moist sub-stratum and absorbs nourishment. On this surface it develops the *archegonia* and *antheridia* as small protuberances.

The **archegonium**, the female sexual organ, arises as a tiny flask-shaped body sunk in the tissue of the prothallus near its notch. Each archegonium consists of two portions : the *ventral*, or swollen lower portion embedded in the

prothallium, contains the female cell or oosphere; and the neck or elongated upper portion consists of a row of cells which burst at maturity. The ventral portion consists of the *egg-cell* or *oosphere* and a small ventral canal-cell (see fig. 393). This, together with another cell which remains surrounded by the neck cells and is called the neck-canal cell, becomes disorganised when the archegonium is ripe, and the disorganised matter then comes out of the neck left open by its bursting. This matter becomes mucilaginous by absorbing water and contains a small percentage of *malic acid* which directs the movement of the spermatozoids, the male cells, towards the oosphere (p. 325).

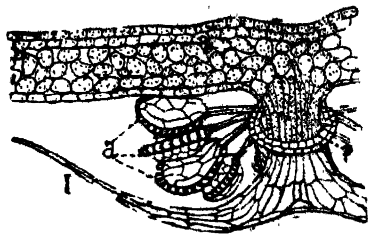


Fig. 388. Section of leaf of *Aspidium*.
I. Indusium ; p, placenta ; a, annulus.

The antheridium, which is developed before the archegonium, is a spherical body with a wall of one layer of cells which like the prothallium-cells are provided with chloroplasts (cf. fig. 394). The inside is filled with a large number of small cells, the spermatozoid mother-cells or *spermatocytes*, each of which gives rise to a motile spermatozoid. The latter is a coiled body with one end considerably enlarged. and the other rather tapering and beset with *numerous cilia* which lash in water and impart a sort of gyratory motion to the male cell. The movement is regulated by the malic acid which is diffused in the neighbourhood of the archegonium. Passing through the open canal of the latter a spermatozoid fuses with the oosphere and thus fertilisation is brought about. The fertilised egg-cell or *oospore*, by a process of repeated division, gives rise to the embryo from which the

Fern plant is developed (fig. 385). The prothallium at first supplies the young embryo with food but it eventually dries up and the young Fern plant produces its own root which absorbs nourishment from the soil and thus makes it independent.

ALTERNATION OF GENERATIONS.

It will be noticed that in the life history of the Fern there are really two phases to be considered. The Fern plant produces only asexual cells, the spores, but these spores cannot produce another Fern without first developing into a prothallium. The reproduction of the Fern plant takes place in two different stages or generations. In one generation only spores are produced—this is called the *asexual* or the sporophyte generation. The Fern plant is the **sporophyte** or the spore-producing plant. In the next generation the spore produces a prothallium on which the sexual organs are developed—this is called the sexual or **gametophyte** generation. The prothallium is the **gametophyte**, or the gametes-producing plant. Thus in the life-cycle of the Fern there is a regular alternation of a spore-producing with a gamete-producing generation. Starting with the spore a tiny thallus is produced from the spore; this is an independent plant having its own rhizoids for absorbing nutriment from the soil and chloroplasts to prepare its own food. On the under side of this plant (prothallus) are next produced the sexual organs, antheridia and archegonia, containing male sexual organs, the spermatozoids, and the female cell, the ovum or egg-cell respectively. After the union of these sexual cells an embryo is produced which while it is young derives nourishment from the prothallus but grows up gradually into an independent Fern plant. From the formation of the prothallium to the development of the sexual cells we get the sexual stage in the life-history of the Fern; from the formation of the embryo to its development into the well-differentiated spore-producing Fern plant we get the asexual stage. The life-cycle is complete when both stages have been passed; then and not till then is the plant visibly reproduced.

The phenomenon of the life-history of a plant being closed in two stages is not manifested by the Ferns alone. Excepting the lower Thallophytes all plants (Ferns, Mosses, and Phanerogams) exhibit a regular alternation of a sexual with an asexual generation in their life-history. In Ferns as well as in Mosses the alternation is perfectly clear, for the sporophyte and the gametophyte are both conspicuous,

In Flowering plants the plant-body is the sporophyte, the flowers are spore-producing organs, the stamens and carpels are sporophylls, the pollen-grain and the embryo-sac are the spores. The difference from Ferns lies in the fact that in Ferns a green vegetative leaf also produces spores; there is no distinction between the ordinary green leaf and a sporophyll, while in Phanerogams the sporophylls are metamorphosed into special structures, the stamens (androphylls) and carpels (carpophylls). Further, the Ferns are *homosporous*; they produce only one kind of spore. Higher plants are *heterosporous*. They produce two kinds of spores: microspores or pollen-grains and a macrospore, called the embryo-sac, inside the ovule.

The gametophytic generation which in Ferns starts with the germination of the spore on the ground is very much reduced in Phanerogams. Pollen-grains, the male or micro-spores, unlike Fern-spores, can not germinate in the ground but only on a suitable stigma. The macrospore, the embryo-sac, is never detached from the parent sporophyte, like the Fern-spore, but remains attached to it. As regards the formation of the prothallus, it is never an independent body in Phanerogams and is extremely reduced. The pollen-tube is the male prothallium; it consists of only two or three cells in the Conifers (Gymnosperms), and produces not spermatozoids but male cells, the generative cells. The reduction in the male prothallium is greater still in Dicots and Monocots for the pollen-tube in these plants is *unicellular*; it consists of a single cell, the pollen tube, and three nuclei of which one is the nucleus of the pollen tube and the other two are the male generative nuclei. The Gymnospermous macrospore, the embryo-sac develops a multicellular endosperm; this is the female prothallium. In it are produced the archegonia. The archegonium consists of a large egg-cell and a few small neck-cells. In Angiosperms, however, the embryo-sac is always unicellular and remains so until fertilisation; nor is there any archegonium. The greatly reduced prothallium here is represented by the antipodal cells, but these cells are not walled cells as in a true prothallium: they are mere nucleated plasmas. The egg-apparatus of the ovule represents the very much reduced archegonium; the synergidæ represent the neck or ventral cells. The endosperm is formed after fertilisation, not before as in Gymnosperms; this is because the endosperm is a prothallium in the latter, while in Angiosperms it is the result of fertilisation. The following scheme enables us to compare the alternation of generations in the life-history of the Ferns and Phanerogams.

	Fern		Conifer		Angiosperm	
	Spore		Microspore or pollen-grain	Macrospore or embryo-sac	Microspore or pollen-grain	Macrospore or embryo-sac
Sexual generation	Green Prothallium		rudimentary Prothallium=Pollen-tube	rudimentary Prothallium=Endosperm	Prothallium represented by pollen-tube.	Prothallium represented by the Antipodal cells
	Antheridium	Archegonium	Antheridium mother-cell	Archegonium	Antheridium mother cell	Egg-apparatus
	Spermatozoids	Ovum	Generative cells	Ovum	Generative nuclei	Ovum
Asexual generation	Fertilised ovum		Fertilised ovum		Fertilised ovum	
	Fern plant (Homosporous)		Conifer plant (Heterosporous)		Angiosperm plant (Heterosporous)	
	Sporophylls		Sporophylls forming rudimentary flowers		Flowers	
	Sporangium		Microsporangia or Anthers	Macrosporangia or Ovule	Microsporangia or Anther	Macrosporangia or Ovule
	Spore		Pollen-grains	Embryo-sac	Pollen-grains	Embryo-sac

There is sometimes a departure from the ordinary mode of sexual reproduction. The female organs are not developed, and the prothallium itself produces the sporophyte purely in a vegetative manner. This sort of asexual reproduction goes by the name of *apogamy*, and is very common in the cultivated Ferns. Similarly in rare cases a prothallus may arise from the tissue of the leaf without the intervention of spores. This is known as *apospory*.

Anatomy of Ferns.—Fig. 389 shows a cross-section of a Fern rhizome. The *epidermis* forms a firm thick layer of dark brown cells. The ramenta are outgrowths of this layer. Below it lies a thick ring of sclerenchyma the cells of which are very thick-walled and brown. Inside this, scattered in the ground-tissue, are a few small bundles—these are the leaf-traces which here and there unite in the margins. In

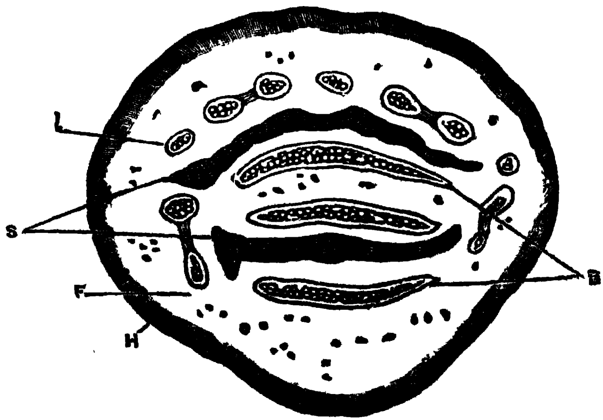


Fig. 389. Transverse section of a Fern rhizome. H, the sclerenchymatous hypoderma; I, ring of foliar bundles; S, sclerenchyma; F, ground tissue.

the central part of the ground tissus are a few larger bundles which are cauline and not leaf-traces. These are separated by plates of sclerenchyma. The bundles in fact

form a more or less cylindrical net-work from which small leaf-traces pass out to the leaves.

The bundle differs from that of higher plants in being concentric, *i.e.*, xylem and phloem do not lie side by side but the phloem entirely surrounds the xylem which lies in the centre of each bundle (fig. 390). Each bundle is a solid conducting strand, there is no pith. The centre is occupied by certain large cells which are *scalariform tracheides* (p. 184, fig. 276, E)—this is the metaxylem. At the two sides of this are the smaller elements of the proto-xylem consisting of *spiral tracheides.* Associated with the tracheides is a layer of wood-cells.

The xylem is surrounded by the phloem. These consist of large sieve-tubes with thin-walled parenchyma. There are *no companion cells.* Outside this is a thin layer of small sieve-tubes—this is the proto-phloem. The whole is surrounded by a layer of pericycle. Each bundle is limited by

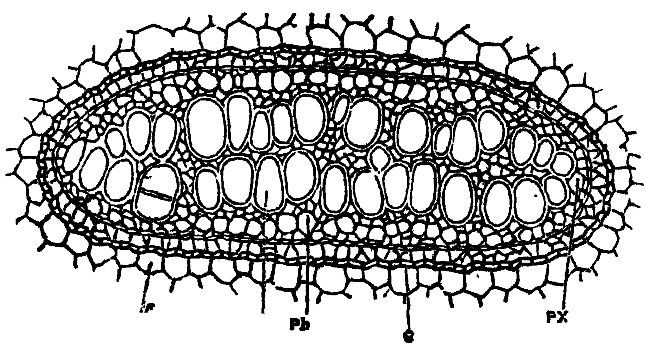


Fig. 390. A Bundle of Fern highly magnified. F. ground tissue; X, xylem tracheides surrounded by wood-cells; Ph, phloem ring; e, endodermis or bundle-sheath; Px, protoxylem.

one or more layers of the cortex lying outside the pericycle. This is the bundle-sheath which contains starch and presents

the characters of an endodermis. There is no cambium and no secondary growth.

In Fern root there is a central solid stele without pith. There are two rays of xylem but it is surrounded by the phloem, the pericycle, and a thick endodermis; the outer cortex is parenchymatous, but inwards it soon becomes lignified and hard.

In the petiole there is one or more bundles which often fuse to form a wide horse-shoe shaped structure in cross-section. The elements are the same as described above. The bundle, however, divides into many parts in the lamina, and the ultimate branches are not quite concentric but have their xylem turned towards the upper surface of the leaf and the phloem towards the lower surface, as in typical dorsiventral leaves.

CHAPTER XXXIII

BRYOPHYTA.

The Bryophytes together with the Thallophytes are called *Cellular plants* as they are made up of simple cells. They do not possess any vessels or such highly differentiated tissues as xylem, phloem, sclerenchyma, etc., and in this respect differ from the Pteridophytes and Phanerogams which are called *Vascular plants.* The Bryophyta includes two classes of plants: the Liverworts (*Hepaticeae*), and the Mosses (*Musci*). The vegetative body of a Liverwort is generally an undifferentiated thallus (fig. 391), while that of a Moss is a cormus, *i.e.*, a differentiated shoot with stem and leaves. There are no true roots but thin thread-like filamentous structures, called *rhizoids,* are produced which function as roots.

Reproduction takes place, as in Pteridophytes, asexually by spores and sexually by spermatozoids and egg-cells, the two latter uniting to produce the germ or the oospore. Both Pteridophytes and the Bryophytes produce their sexual cells in *Antheridia* and *Archegonia* and hence are together referred to as the *Archegoniatae.* A regular alternation of generations between the sporophyte and gametophyte also characterises the Bryophytes.

Marchantia (Fig. 391) may be taken as a type of the Liverworts. The plant grows extensively in cool and moist hilly places, forming dirty green patches on the ground. The vegetative body is a flat-lobed thallus which remains attached to the ground by means of thin unicellular rhizoids. The upper surface shows many cup-shaped depressions each of which contains a number of green, flat, biscuit-shaped bodies called gemmae. These are special kinds of buds which are detached from the thallus and germinate independently to give rise to new plants, thus securing a very rapid vegetative multiplication. The sexual organs

antheridia and archegonia, are borne on erect branches which spring from the thallus. The terminal portion of these branches expands into a much-branched head in which the antheridia and archegonia are developed in small flask-shaped depressions. The structure of these sexual organs corresponds to that described below in connection with Moss.

Fig 391.

Marchantia—A, thallus; B, capsule ejecting spores; C, spores. At the top of the stalks arising from the thallus are archegonia and antheridia.

Fig. 392.

A Moss—*Polytrichium*; A, the plant with a capsule; B, a leaf; C, the sporogonium with calyptra.

MUSCI—MOSSES.

The Mosses live in dense colonies forming beautiful green carpets on moist rocks, on moist shady ground or walls, and even on the moist bark of trees. The body of

a Moss plant consists of a short slender stem which decays slowly at its lower end and grows continually at its upper leafy extremity (fig. 392). There are no true roots but the lower end of the stem gives off numerous slender brown multicellular *rhizoids* which penetrate the soil and act like root-hairs (fig. 7). The upper erect stem is beset with numerous small green spirally arranged leaves. The clustered habit of the plants enables them to retain rain-water or dew for a long time and the delicate leaves are adapted to absorb moisture.

The apical growth of the stem usually terminates about the cold season when the upper bud bears cup-like rosettes of leaves, reddish or brownish in colour, which form what is popularly called the Moss flower, though there is nothing in common with the flowers of Phanerogams. The Moss flower is really a receptacle in which the male and female sexual organs, antheridia and archegonia, lie concealed amongst the whorl of leaves (*perichætium.*) Moss plants may be monœcious, when both kinds of sexual organs are borne on the same plant; or diœcious, when the antheridia and archegonia arise on different plants.

The antheridia (fig. 394) are stalked, club-shaped bodies which contain a large number of spermatozoid mother cells each of which produces on maturity a slightly twisted filamentous spermatozoid provided with only two cilia at the narrow end (S). The archegonia (fig. 393) are flask-shaped bodies with a long neck and a swollen base. The central portion of the neck is occupied by a row of cells, the *neck-canal cells,* which at maturity swell up by absorbing water and cause the rupture of the neck. The swollen base, called the *venter*, encloses a large cell which divides into the female egg-cell and a ventral-canal cell. The latter lies just below the neck-canal cells and undergoes disorganisation with the latter when the arche-

gonium is ripe and ready to open the neck. These canal-cells become mucilaginous with water and exert an attractive stimulus on the spermatozoids through the diffusion of cane-sugar (chemotaxis, p. 325). For fertilisation water is indispensable and so the process takes place mostly during the rains. A spermatozoid swims through the canal of the archegonium and reaching the venter fuses with the egg-cell. The fertilised egg-cell then divides rapidly to form a multicellular embryo.

Fig. 393. Archegonium of Moss. V.C., ventral canal-cell. E, egg-cell. B, neck.

Fig. 394. Antheridium of Moss—s; mother-cells of spermatozoids S.

The embryo is not detached from the plant but gives rise to an elongated and stalked body termed the capsule. The Moss capsule appears to arise from the centre of the

top of the stem and is borne on a long stalk. The capsule contains countless *spores*. So long as it is young its apex is protected by a dry fibrous hood termed the *calyptra* (fig. 395)

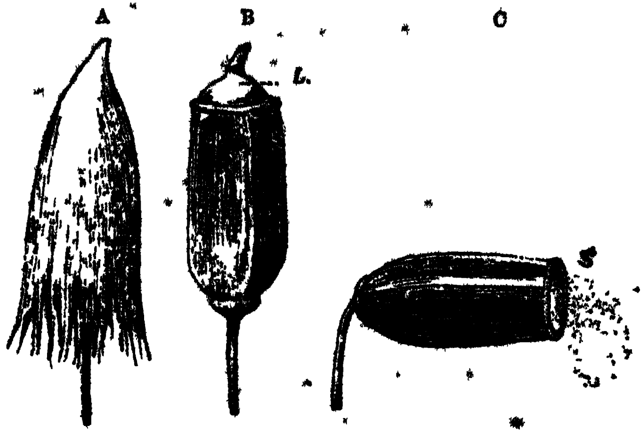


Fig. 395. The Moss capsule or sporogonium. A, the young capsule with the calyptra; B, the same later stage, the calyptra is shed but the mouth of the capsule is covered by the lid L, C, the ripe capsule with the lid shed and spores (S) coming out.

like the root-cap of roots. This calyptra is thrown off when the capsule is ripe and then it looks like a tiny poppy fruit surmounted by a small lid (*operculum*, L). The lid eventually drops also and the spores (S) now come out. The rim or mouth of the capsule is provided with several very delicate tooth-like outgrowths which form a fine membrane partially closing the opening. These outgrowths (termed the *peristome*) execute peculiar hygroscopic movements, opening out in dry weather and closing when it is moist, and thus help the dispersion of the spores. The spores are unicellular bodies with two walls. The outer wall bursts on germination and the inner grows out into a tube which branches repeatedly and produces a filamentous thallus called

the *protonema*. The Moss plant itself grows up from a bud produced on the protonema.

ALTERNATION OF GENERATIONS IN MOSS.

The Moss plant is the gametophyte: it produces the gametes, the sexual cells, in the archegonia and the antheridia, The Moss capsule resulting from the union of the sexual cells is the sporophyte; it is also called the *sporogonium* and it produces spores, the asexual reproductive bodies. The sporogonium forms a distinct asexual generation but it remains throughout its existence united with the sexual generation (the plant itself) and draws nourishment from the latter very much like a parasite. In this respect the alternation of generations in Moss differs from that in Fern, for in Ferns the two generations are independent plants.

Following the scheme laid down on p. 411, the alternation of generations in Moss and Fern may be compared thus :—

	Moss	Fern
Sexual generation	Spore	Spore
	Protonema	
	Moss plant	Prothallium
	Antheridium — Archegonium	Antheridium — Archegonium
	Spermatozoid — Ovum	Spermatozoid — Ovum
Asexual	Sporogonium	Fern plant
	Spore	Spore

A detailed comparison is shown in the following table.

Fern	Moss
1. The plant is the sporophyte.	1. The plant is the gametophyte.
2. The sporophyte is the fully differentiated cormus.	2. The gametophyte is the morphologically differentiated cormus.
3. Spore on germination produces a prothallium—the sex-bearing generation or the gametophyte.	3. Spore on germination produces a protonema from which the Moss plant is developed—this is the gametophyte.
4. The gametes of the prothallium unite to produce an embryo which develops into an independent Fern plant or sporophyte.	4. The gametes of the Moss plant unite to produce an embryo which develops into the Moss capsule, the sporophyte, and remains attached to the gametophyte throughout its life.

CHAPTER XXXIV.

THALLOPHYTA.

The Thallophytes are leafless cellular Cryptogams. They are plants which do not in general show any differentiation into stem and leaves. As a rule, Thallophytes reproduce asexually by spores which arise in special chambers or sporangia, when they are called *endospores* or are cut off and separated from the plant-body at special parts, when they are called *exospores*. Sometimes the spores are naked cells provided with cilia and move about in water. Such spores are termed swarmspores or **zoospores**. Reproduction also takes place sexually but the sexual cells are very simple. Sometimes conjugation takes place between two outwardly similar cells called **gametes**. When the gametes are motile they are called *planogametes*, and when non-motile they are *aplanogametes*. In the higher Thallophytes the sexual cells are differentiated into motile ciliated male cells, the spermatozoids, and large non-motile female cells, the oospheres or egg-cells. The spermatozoids develop in antheridia; the oospheres in **oogonia** which are much simpler than the archegonia. By the conjugation of similar gametes a **zygote** or zygospore is formed. By the fertilisation of the oosphere by a spermatozoid an **oospore** is produced. The former mode of sexual union is termed **isogamy**, the latter **oogamy**.

The Thallophytes are usually divided into two classes: (1) the Algæ, and (2) the Fungi. The distinction lies in the fact that Algæ are green and hence autophytes (p. 299), Fungi are never green; they are saprophytes or parasites. The Algæ can manufacture complex organic compounds

from the inorganic constituents of the earth; Fungi can not do that; they live upon living or dead organic matter, either animals or plants. This difference in habit is due to the presence of chromatophores, chiefly chloroplasts, in all Algæ, which are totally absent from the cells of all Fungi.

The Algæ are Thallophytes characterised by the presence of the green pigment chlorophyll in their cells. But this does not mean that they are all green in appearance. In many cases, specially in those growing in sea water (the marine Algæ), other colouring matters, such as brown or red, mask the green chlorophyll. The Algæ are all aquatics, the lower and simpler forms sticking to moist rocks or walls or tree-trunks as green patches. Marine Algæ are larger and are commonly differentiated into leaf-like expansions or thallus. Fresh-water Algæ are all green and either filamentous or unicellular.

CHLOROPHYCEAE.

This group includes the majority of fresh water Algæ in which the green colouring matter chlorophyll is not accompanied by other pigments as in other groups of Algæ. It includes also some of the most interesting unicellular forms.

The Green Algæ are among the most widely distributed of plant-forms. They occur practically in all places where enough moisture can be had, in rivers, ponds, ditches, nullahs, in all kinds of stagnant water, in damp earth, walls, barks of trees, decomposing moist leaves, etc.

The **Desmids** are unicellular green Algæ found in ponds, ditches and wet places, commonly attached to the free floating filamentous fresh-water Algæ. The distinguishing characteristic of these algal cells is their almost invariable division into two symmetrical halves often separated by a circular constriction in the middle. The forms presented are some of the most beautiful of fresh-water Algæ. The cell-wall usually consists of two distinct valves whose edges meet in the plane of constriction. Multiplication takes place both by cell-division

and by conjugation. The former which is the vegetative mode takes place by the forcing apart of the two valves, a new cylindrical piece of membrane being interposed. Subsequently a transverse wall is formed in the median plane of this cylinder, the separated halves of which then grow up into new valves. Conjugation takes place by two Desmids approaching each other when the protoplasmic contents of each rounds off. The outer walls of each split at about the middle and then the entire protoplasts pass out to fuse into each other, either wholly or partially separated from the parent-cells. The result of the fusion is a zygote which then surrounds itself with a wall, the outside being provided with numerous spinous processes. The zygospore thus formed enters into a period of rest after which germination takes place.

SPIROGYRA.

This is a very common fresh water Alga. It forms extensive green slimy floating masses. It is a filamentous Alga, consisting of a row of cylindrical cells forming long threads or filaments, The character which distinguishes it from all other Alga is the peculiar development of the chloroplasts in the form of bands or ribbons which are spirally coiled at about the circumference of each cell. There may be only one spiral band in a cell or it may contain as many as eight spiral bands, the number depending on the width of the cells. When two or more spiral bands occur they cross regularly and thus form more or less complex lattice-works.

Fig. 396. Two filaments of Spirogyra—showing stage just before conjugation.

Structure:—Each filament consists of barrel-shaped cells joined end to end. The walls are of cellulose and the outer surface of the walls swells slightly in contact with water; hence the slimy or gelatinous nature of the floating masses. Each mature cell contains a colourless layer of protoplasm lining the cell-wall with a large vacuole in the centre filled with a colourless cell-sap. Suspended in this vacuole but kept stretched by threads of cytoplasm connected with the lining layer is a large nucleus.

The chloroplasts are the most attractive and distinguishing feature of the cell. Each chloroplast lies embedded in the parietal protoplasm and forms a band twisted round the interior of the cell in a spiral manner. The bands have serrate margins and contain a few star-like refractive bodies termed the *pyrenoids*. The latter produce starch-grains.

Life history:—In spring, the season when water is plentiful, the plant flourishes; growth takes place in the cells by the simple process of elongation and subsequent division. The reproduction of the plant takes place only by the sexual mode; there are no asexual reproductive cells or spores, and the sexual mode even is one of the simple. There is no distinction into male and female cells; the two pairing cells are to all appearance similar and are called **gametes**. The sexual process, called conjugation (from which the name of the sub-class *Conjugatæ* to which Spirogyra belongs), consists essentially in the fusion of two gametes; these are not provided with cilia (aplanogametes) and hence exhibit no ciliary movement. They are developed from the contraction, condensation, and rounding off of the protoplasm of two different cells, each cell producing a gamete.

Conjugation takes place generally by the end of summer or when the level of water is low. Two filaments come to lie side by side; the contents of some of the cells of one filament

contract and becoming rounded off turn into gametes. The cell-walls at the same time protrude out towards the other filament the cells of which then show a similar behaviour. The protruding cell-walls of both then touch, the separating wall is absorbed and a clear passage is formed.

The gametes of the first filament then pass over into the cells of the other filament and fusing in pairs with the gametes of this filament form zygospores or zygotes. Each of these then surrounds itself with a firm wall and after a period of rest germinates to produce a new filament. Sometimes conjugation takes place not between two separate filaments as above but between the two halves of the same filament folded into two.

FUNGI.

Structure —As a class Fungi are characterised by the absence of chlorophyll and are distinguished from all other plants by the relatively simple structure of their vegetative organ. Indeed, structurally they are the simplest of all plants. The body of a young actively growing Fungus consists entirely of simple whitish tubular threads called **hyphæ.** These hyphæ are made up of elongated cells with very thin walls and with or without partitions. They ramify in all directions, penetrating every part of the substratum which is either a decaying organic debris or a living organism. The mass of the entangled hyphal threads constitutes the body of the Fungus termed the **mycelium.** In the larger Fungi, such as the Mushrooms, the hyphæ are woven into a more or less solid columnar structure forming a false tissue or pseudo-parenchyma.

The mycelium is said to be *septate* when its hyphal threads have transverse walls, and *non-septate* when no such walls exist, a continuous channel running through the hyphæ of the mycelium. Such a mycelium is said

to be a COENOCYTE. The cell-wall is always very thin and consists of CHITIN and not of cellulose as in all other plants. Neither the walls nor the contents of the cells are carbohydrates, for starch, sugar, and cellulose never occur but are replaced by fat globules and glycogen as cell-contents.

Mode of nutrition.—As a class Fungi are either parasites or saprophytes (see p. 304). They obtain the whole of their food from the nutrient substratum and most of them also require air (oxygen) for respiration. They do not contain chlorophyll nor any chromatophore, and hence are incapable of assimilating carbon from the atmospheric carbon dioxide. The parasitic Fungi depend for their food on the living bodies of animals and plants which they decompose by secreting certain ferments, and then absorb the products of decomposition. These parasitic Fungi are dangerous pests destroying such important vegetables as potato, wheat, rice, and many fruits. Some, however, form helpful life-partnership with the roots of many plants (see mycorhiza, p. 301). The saprophytic Fungi form an extensive class, although in most cases their mode of life cannot be distinguished from the parasitic forms. They live on decomposing animal or vegetable remains such as rotten cow-dung, putrefying carcase, decaying leaves and stem and so on.

The absence of any compact structure in the mycelium of a Fungus is evidently connected with its mode of life, for since all its food is derived from the material on which it lives, an abundantly branched cellular tissue is indispensable for ramifying into the substratum and for absorbing the food, exactly like the root-system. Like the root-system of higher plants the mycelium absorbs food, but the former can absorb only raw food for the plant to assimilate, whereas the latter, the body of the fungus, absorbs everything required for its life. This explains why Fungi have a simple thalloid

structure; they need not produce any aerial shoot for their mode of life renders this unnecessary.

The peculiar mode of life of the Fungi is in principle diametrically opposed to the metabolic processes taking place in higher plants. The latter prepare very complex organic matter from the stable raw substances in their environment, and the organic matters thus produced lock up a great store of energy potentially. The action of the Fungus, however, is such that these complex matters are broken up, simplified, disintegrated into simple compounds and in the process a large amount of energy is set free as *kinetic energy*. It is this energy which is directly available to the Fungus for doing further work which consists in dislocating the work of plants and animals, helping the natural decomposition of organic matters, and multiplying their own species.

That energy is set free by the growth of Fungi upon organic matter is shown by the fact that heat is evolved during the decomposition. Rotting fruits and vegetables, rotting straw and cow-dung, feel warmer than when fresh, and if kept in a confined place become very considerably heated.

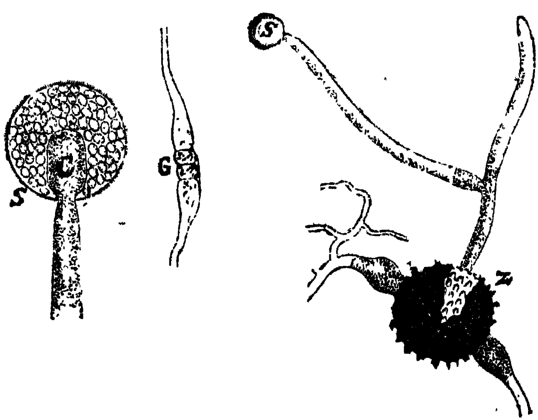
Reproduction and life-history.—Although the vegetative body of the great majority of Fungi remains more or less buried in the substratum, their reproductive organs always seek air and light and come out as aerial sprouts. This is an instance of chemotropic and phototropic movement (p. 325). The advantage thus secured is great, for the reproductive bodies are generally asexual unicellular spores which are produced as minute grains in profuse quantities at the tips of the aerial hyphae which, when heated by the sun, or in a dry atmosphere, scatter broadcast their innumerable spores. A Fungus develops from the germination of a spore on a suitable substratum, at first as a tiny white tube which the spore puts out, and then this tube elongates, divides, and ramifies in all directions penetrating into the substratum. After some time, about the period of reproduction,

some of the hyphæ turn and grow upwards into the air as aerial hyphæ and terminate in a club-shaped body. At this part innumerable spores are formed. Sexual reproduction also takes place in many instances but a regular alternation, as in the Pteridophytes and Bryophytes, is altogether wanting. A few Fungi are described below :—

MUCOR (*Mucor mucedo*).

Structure.—This is a very common mould formed as a white downy coat on many articles, such as old damp boots and other leather goods, old confections, moist bread crusts, preserved fruits and animal excreta. It can be artificially cultured by keeping a moist bread in a damp, dark, and warm place. It is a saprophyte. The mycelium is much-branched and filamentous. The hyphæ are unseptate, *i.e.*

Fig. 397. Fig. 398. Fig. 399.



MUCOR MUCEDO.

Fig. 397. Sporangium (s) with numerous spores and columella (c) Fig. 398. Formation and union of gametes (G). Fig. 399. Germination of zygospore (Z) ; an erect hypha bearing a sporangium (s).

they are long tubes without transverse walls; and contain oil globules and many nuclei.

Reproduction :—From the mycelium a number of erect aerial hyphæ are produced; these are called **sporangiophores** (or **gonidiophores**) being the stalk of the *sporangia* (or *gonidangia*) formed at the terminal parts. From the apex of such an aerial hypha a single spherical sporangium (or gonidangium) is cut off by a transverse wall which then gradually protrudes into the cavity of the sphere as a short swollen stalk called the **columella** (fig. 397). Within the sporangium numerous oval walled spores are produced by the repeated division of the protoplasm and the nucleus. These spores are hence *endospores*. They lie at first embedded in the slimy contents of the sporangium, which swell by absorbing water and finally rupture the sporangial wall. The spores are then scattered and falling on a moist substratum produce other Mucor plants.

The large number of spores secures a very rapid multiplication of the Fungus by asexual means. Sexual reproduction also takes place under certain conditions. The mycelium then produces two special club-shaped hyphal branches, the *gametophores* (fig. 398), which approach each other. When the swollen tips of these hyphae come in contact a transverse wall is formed below each swelling; the gametes thus cut off then fuse. The wall separating the two is absorbed and the conjugating cells produce by fusion a single **zygospore**, the outer wall of which gradually thickens and develops warty protuberances. This is another instance of conjugation (see p. 425).

After a period of rest the zygospore (Z, fig. 399) germinates by bursting its outer hard wall and puts out a short hyphal filament. This hypha, however, at once terminates in a sporangium (s) and the spores produced from this falling on a moist ground develop into the usual much-branched

mycelium of the Mucor. There is no regular alternation of generations.

Sometimes the gametes do not fuse but develop independently into mycelia. They are then called **azygospores.** Under certain conditions the hyphæ form transverse walls and appear like chains of cells. These cells (chlamydo-spores) may break up and produce new mycelia. Sometimes these cells behave like yeast-cells (see p. 424) and give rise to alcoholic fermentation. This is known as the *torula condition* of Mucor.

EUROTIUM.

Structure—*Eurotium* is another mould like the *Mucor.* It is formed as a greenish down on softened fruits and on decomposing vegetal matters generally. It can be often cultured artificially by keeping moist cow-dung cakes in a damp but warm and dark place. The mycelium here is very much like that of the *Mucor,* being made up of entangled filaments of a much-branched system of hyphæ which ramify in the substratum. The hyphæ however are *septate i.e.,* they are provided with partition walls at short distances, and in this respect differ from those of the *Mucor.*

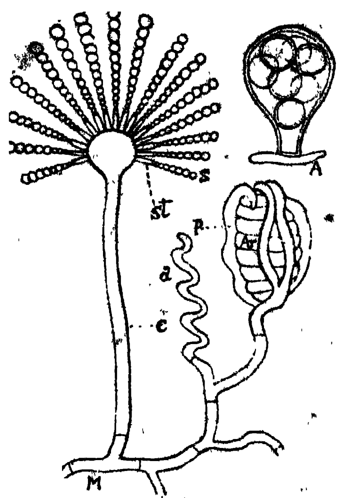


Fig. 400. Eurotium.

Reproduction takes place both sexually and asexually, the former being much more complex than the corresponding process in the Mucor. **Asexual** reproduction takes place by spores which are produced at the end of aerial hyphæ

termed **conidiophores** (fig. 400, C). The head of the conidiophore swells up into a spherical body on which arise radiate-fashion a large number of peg-shaped out-growths called **sterigmata** (St). From the apex of each sterigma small spores called conidiospores or **conidia** (exospores, s) are abstricted in chains. The conidia are produced in enormous quantities and break away from their sterigmata, and are blown and scattered by the wind. On reaching a suitable substance they develop directly into a much-branched mycelium which then repeats the same process.

In the sexual reproduction the end of a long hypha of the mycelium becomes spirally coiled some four or five times and constitutes the female organ or the **archicarp** (a). The spiral is non-septate and is differentiated into (1) an upper part constituting the terminal part of the archicarp called the **trichogyne**, and (2) the lower swollen part called the **carpogonium**. Just below the archicarp (Ar) the same hypha puts out branches one of which (p) develops very fast and arching over the archicarp reaches the trichogyne. This branch is the male organ and is called the **pollinodium**. It contains the male plasma. The walls of the trichogyne and the pollinodium break away where they touch and the protoplasm of the latter is poured into the archicarp. There conjugation takes place and is immediately followed by the development of a large number of sterile hyphæ which completely surround the archicarp and by repeated branching form a thick covering of pseudo-parenchyma termed the **perithecium**. During this process the hypha of the carpogonium becomes septate, and the septated cells grow up and again become septate. In this way a tissue resulting from the fertilisation of the carpogonium originates inside the perithecium. Some of the end-cells of this tissue develop into special sporangia called **asci** (A). Each *ascus* develops within it eight spores called *ascospores*.

The mature carpogonium with the perithecial layer forms the ascus fruit or ascocarp which when ripe breaks up, so as to expose the asci, and then bursts, and the ascospores are set free to be scattered by the wind. Each ascospore is of a biconvex shape and germinates as usual to give rise to the mycelium of Eurotium. This mycelium produces, like that which proceeds from the conidia, at first conidiophores and then the sexual organs. A regular alternation of sexual and asexual generations is not traceable.

YEAST.

The Yeast is one of a group of the simplest Fungi. It sets up alcoholic fermentation in grape juice in the manufacture of wine and thrives best in substances rich in sugar. It is an unicellular Fungus of spherical, oval, or cylindrical cells. There is no proper mycelium nor a hypha, though sometimes the yeast-cells remain for a time united in chains. Reproduction takes place chiefly by *fission*. Each gives rise to a tiny outgrowth which gradually increases in size and is finally abstricted like the conidia of *Eurotium*. These conidia-like daughter-cells repeat the process and in this way the plant rapidly multiplies, so long as there is enough sugar to be fermented into alcohol. This process is known as pullulation or gemmation—fundamentally a vegetative method of reproduction. Under unfavourable conditions, when, for instance, there is no sugar in the substratum, the Yeast-cells swell up and form sporangia. The nucleus is divided into several nuclei around each of which protoplasm collects by a process called *free cell-formation*. Several spores are formed within each sporangium and a part of the protoplasm is left over. These spores are similar in origin to the ascospores of *Eurotium*. Eventually the wall of the sporangium bursts, the endospores come out, and are dispersed by the wind. Coming to a fresh field rich in sugar,

they split their outer wall and put out short protuberances which by gemmation rapidly produce a colony of Yeast-cells. Sexual reproduction is not known.

Generally, the action of Yeast in setting up fermentation in a saccharine solution may be represented by the chemical equation,

$$C_6 H_{12}O_6 = 2C_2 H_6 O + 2CO_2$$

Sugar Alcohol Carbon dioxide.

The evolution of carbon dioxide by the Yeast is a case of anaerobic respiration (p. 309); it occurs even when oxygen is excluded. But it does not cease when oxygen is supplied, for the Yeast plant has acquired the habit of bringing about fermentation spontaneously.

THE MUSHROOM.

The mushroom is a *saprophyte* lying on decomposing organic matters, such as cow-dung, rotten bamboos, decaying leaves, etc. The little umbrella-like body which is seen above ground—that which is called the toad-stool or Mushroom (fig. 401)—is merely the fructification bearing the reproductive bodies called *spores*. If the head (*pileus*) of the mature Mushroom is laid on a sheet of paper for a few hours, the paper will be covered by a dark coloured powder; these are the spores. The aerial fructification is short-lived, it perishes as soon as the spores are scattered. The real vegetative body of the fungus lives under-ground ramifying in the substratum in the form of a dense net-work of white filaments or hyphae—this is the mycelium.

Reproduction takes place only asexually by spores; sexual reproduction is entirely absent. The spore-bearing aerial fructification is a dense compact mass of hyphae which forms a stem-like body, called the stipe, terminating in

a swollen umbrella-like head called the pileus, (fig. 4, b). The under surface of this bears a large number of delicate vertical plates or lamellæ radiating from the stipe to the edge of the pileus. These are also called the gills from their resemblance to the gills of fishes. The gills or lamellae bear the spores on their surface (fig. 402). As long as the spores are undeveloped the young pileus is closed at its lower part by a veil or velum which is ruptured on maturity and then forms a torn ring at the base of the pileus (see fig. 4, *a*).

Fig. 401. The Mushroom —a, the pileus, below the expanded head is the torn velum.

The lamellæ are plates of interwoven hyphæ. In a section each lamella shows a central part, known as the **trama** (Fig. 403, *t*), made up of hyphæ which curve outwards towards the surface where they end in small close-packed cells. The layer is called the **sub-hymenial layer**. It bears the superficial layer of cells, called the **hymenium**, where the cells are slightly elongated and arranged in the palisade manner. The hymenium is the generative layer. It consists of two kinds of cells: (1) sterile cells called *paraphyses* (fig. 404, p), and (2) fertile or spore-producing cells called **basidia** (b). Each basidium bears at its apex

two or four slender processes called **sterigma** (st) and from each sterigma a single small rounded cell or **basidio-**

Fig. 402.

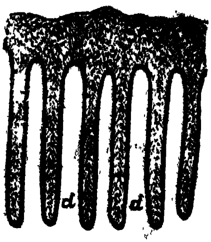


Fig. 403.

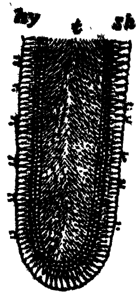


Fig. 404.

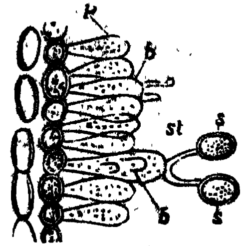


Fig. 402. The gills (d); Fig. 403. A single gill magnified, (t) the trama; on the surface is the hymenium (hy). Fig. 404. The hymenium greatly enlarged.

spore (s) is cut off. The spores are produced in very large quantities and are readily dispersed by the wind. After the spores are developed and scattered the aerial fructification rots away.

CHAPTER XXXV.

ECOLOGY.

Plants try to *adjust* themselves to their surroundings as seen in the evident movement of parts of their body, such as the closing of stomata, or a change in the position of leaves, stems and roots during growth, and so on (see p. 315). This constant adjustment to external factors has brought forth certain structural changes necessary to the well-being of the plant. These are called **adaptations**, and plants are said to be adapted to their environment. Thus, water-plants are *adapted* to live in water; they have their own peculiar structure which enables them to live in an aquatic environment; land-plants are adapted to live on firm land, and so forth.

Water and light are the two most important factors which vastly influence the mode of life of the plants, and hence also their form and structure. Other factors, such as the fertility of the soil and the conditions of the atmosphere, are of course also important. But the supply of water to the plant is the first condition of its life, and its structure is accordingly moulded to suit the nature and amount of water-supply. In this respect there are the two extremes of plants which live in water or in excessive water-supply, and those which live in very dry land with very poor water-supply; midway between these stand plants which have neither too much nor too small water-supply. These latter are the ordinary land plants or **Mesophytes**; while the other two are water-plants or **Hydrophytes** and desert-plants or **Xerophytes**. Generally speaking, hydrophytes grow in water, xerophytes in very dry soil, and mesophytes in ordinary moist soil.

WATER-PLANTS (Hydrophytes).

Water-plants may be broadly divided into three groups—

(1) *Floating aquatics*, such as the Water-hyacinth, the Pistia (Bara-pana), Lemna (Chota-pana) etc, which have rosettes of leaves and tufts of fibrous adventitious roots arising from a very short stem. They float freely by their large, spongy leaves, and have sometimes special floating devices, such as the swollen bladder-like petioles of Water-hyacinths. The tuft of *floating roots* (p. 25) helps the plants to keep equilibrium and prevent their toppling over under the action of currents.

(2) *Submerged aquatics*, such as Potamogeton, Vallisneria, etc., have their vegetative organs entirely submerged and send up only the flower in the air. They have very simple, generally thin and long or ribbon-like leaves.

(3) *Amphibious plants* which are partly submerged and partly aerial, such as the Lotus, Water-lilies, and Water-chestnut (Trapa), which have a trailing or creeping rhizomous stem lying in the mud and long-stalked floating leaves; also such plants like the Jessiuea (Keshardam), Myriophyllum, Limnophila (p. 65), Kalmi-shak (p. 375) etc. with long aerial shoots above the water. Some of these plants are *heterophilous*, possessing not only large floating leaves, but also dissected sub-merged leaves (p. 64) and ordinary small aerial leaves in addition. The floating leaves are broad, undivided and entire with a petiole which has the power of adjusting its length according to the depth of water.

The structural features of aquatics are:—(1) Roots are never thick, hard or woody but are delicate, greatly elongated, fibrous, and adventitious, often freely branching. A root-cap is often wanting, specially where the

root is free floating and has not to encounter particles of soil. Root-hairs are also often absent, for the whole sub-merged part of the plant can absorb nutriment from the water through the epidermis.

(2) The stem is either trailing or creeping or rhizomous, or greatly abbreviated as in the freely floating plants and the sub-merged species which produce only a rosette of leaves. Branches, however, arise very freely, for aquatics multiply very rapidly by vegetative organs such as stolons, offsets, etc. (p. 317).

(3) Leaves are of various forms: the submerged ones are either ribbon-shaped or dissected, the floating forms are broad, large, entire and highly spongy.

Water-plants are as a rule perennials. They always produce flowers on an aerial stem or have floating flowers (Water-lilies), so that fertilisation is always aerial. They are, however, lavishly multiplied vegetatively.

Anatomically water-plants are characterised by a soft spongy parenchymatous ground tissue traversed by large air-passages or canals which form the ventilating system of the plant. This *aerenchyma* (p. 213) is necessary, for the plants are more or less cut off from external air which they require, specially the oxygen, for respiration. Further, it serves to make them light and buoyant so that they can have as much air and light as possible.

In Dicot aquatics a well defined cortical portion is recognised, but this is always traversed by the air-cavities; in Monocot aquatics and in the Lotus family (of Dicots) a cortical portion can not be distinguished from the rest of the ground tissue. Often in elongated floating or sub-merged stems, specially of Monocots, the outer cortical portion is traversed by long strands of fibres which give the necessary pliability along with elasticity required to cope with currents of water.

The vascular bundles are greatly reduced and *wood* is not formed even moderately. In Dicot aquatics they are formed in a ring, but always remain rudimentary and disposed *centripetally*. There is no secondary growth in thickness and the centripetal position makes the stem pliant and enables it to sway this way and that with currents. The lignification in the xylem is very poor, for in the presence of water lignin is not much formed. In Monocot aquatics the bundles are scattered in the ground tissue and are similarly greatly reduced, there being only a few xylem elements in the centre surrounded by a soft phloem and a parenchymatous bundle-sheath ; the phloem undergoes no reduction for it has to carry the proteids. The xylem is reduced for the plant does not require a well-developed tissue for conducting water. A thick cuticle is never present and the formation of cork and bark is entirely precluded.

3. The epidermis is very thin, without the cuticle, in the submerged parts. The cells often contain chlorophyll. This is because of the weak light which the submerged parts get. The chloroplasts must be superficial to absorb the small quantity of light which reaches the plant under water. STOMATA are absent from the submerged parts, for transpiration is obviously excluded as it is unnecessary. Stomata are present only on the upper surface of floating leaves which have a dorsi-ventral structure with an upper palisade and a lower spongy mesophyll. This distinction is absent in submerged leaves which are therefore *isolateral*. Floating leaves have a coating of wax (Lotus and Water-lilies) or of hairs (Pistia) on the leaf so that the surface is *unwettable*, the water rolling away into small drops.

LAND PLANTS.

Transpiration is the most important phenomenon in the life of land-plants, for it keeps up a regular circulation

of food-matters in the plant body very much like the circulation of blood in animals. The process itself is regulated by light. And since the water-content of the soil differs at different places and varies even in the same place with the seasons, there are definite adaptations for regulating transpiration. For, there must be a balance between the intake of water from the soil and its output by transpiration from the leaves. If there be excess of transpiration the plant withers, if of root-absorption and a diminished transpiration there is the risk of choking the plant with water and of its losing a healthy tone. The adaptations that are found in land-plants are therefore meant to keep up this balance, or, in other words, to regulate transpiration.

1. The roots branch and ramify in every direction, wherever there is moisture, and are provided with root-hairs at the younger parts. The tip of the root is very sensitive to moisture and leads the way for the root-hairs to perform their work of absorption. The older parts of the root which cannot move freely and hence can not carry on the function of absorption become gradually stouter and thus serve to fix the plant fast to the soil. A further exquisite adaptation in this direction is the development of branches from the convex parts of the main and the branch roots. By this means the root is prevented from straightening out as it grows old and becomes stouter and stiffer, and its zig-zag form is maintained; thus a large volume of the earth is bound up by the root-system, so that a strong wind may not easily uproot the plant. To afford protection to the root-tip which has to make its way through hard particles of soil, a root cap is provided. Moreover, the branching and ramification of the root-system are correlated with the branching of the aerial shoot. Where, as in Palms and Bamboos, there is a rosette of leaves at the top, there are also whorls of roots from the lower part of the stem, and

where, as in Dicots generally, the trunk is amply branched and the leaves form an extensive evaporating surface, the root system also is copiously branched underground so as to form an equally extensive system of root-hairs for absorbing moisture.

2. The stem is elongated, and since it has to keep itself erect, mechanical tissues of various forms are so developed as to make it sufficiently rigid. And, further, as the distance between the burrowing root and the assimilating leaves goes on increasing, long tubes or ducts or the vascular bundles are very fully formed; so much indeed that in an old trunk there is nothing but solid hard wood and thick layers of bark. Even in such delicate or smaller plants as Grasses there is a preponderance of mechanical tissues (p 270) for the function of support, and a degree of safe rigidity is the first requirement of the aerial shoot. In large plants the crushing effect of the increasing weight of branches and foliage is balanced by a continuously growing mass of hard lignified wood, while in younger plants, where growth is rapid, mechanical tissues are not much formed as they retard elongation and rapid development. The greater part of the inner and older wood of a tree is dead and serves only a mechanical function and only the outer younger ring of wood is active in transport work. Hence the importance of securing adequate protection for this most vital part of the plant by the formation of cork and bark with their various tannin or gum excretions which act as preservatives against insects and pests.

3. The adaptation in the foliage leaf of land-plants is one of the most exquisite of its kind, for next to roots the leaves are perhaps the most important organ of a plant. While very young they are rolled or folded or tucked up in the bud safe from danger and the young buds are further protected by scale-leaves and stipules. As the leaf unfolds

the stipules or scales fall away or are removed from the point of vantage which is now occupied by the lamina, and the petiole where present serves to hold it in the correct angle and position so that just the required intensity of light and air may be had without much difficulty.

Anatomically the leaves of land-plants are admirably fitted to carry on the important functions of transpiration, assimilation and respiration. The epidermis is provided with a more or less thick cuticle which prevents evaporation and undue loss of water from the leaf surface. For transpiration a special apparatus, the stomatal apparatus, is developed and the stomata are scattered in large numbers, not on the upper face of the leaf where the direct rays of the sun would undoubtedly injure the guard-cells, but on the lower shady surface. And for utilising the direct rays of the sun an upper palisade tissue is differentiated from a lower spongy tissue, and this gives rise to the dorsi-ventral structure of the lamina. And in order that transpiration and aeration may go on favourably, the stomata open directly on large respiratory cavities in the spongy mesophyll tissue (p. 235). The infinite ramifications of the vascular bundles in the form of fine veins or nerves bring in at every instant supplies of raw food through the xylem which on being worked up into organic compounds are speedily removed by the phloem.

Mechanical tissues are not required in Dicot leaves, for their reticulate venation protects them from the tearing action of wind. In Monocots, however, the venation does not give sufficient strength and hence mechanical tissues are always developed and disposed suitably (see structure of leaf, p. 238).

In those parts of the Tropics where there is a long dry season, there is an annual shedding of leaves, as in the Shimool, Aswatha, Bael and many large trees. This periodic defoliation is an adaptation to prevent loss of water at a time when water is very scarce and can hardly

be transpired without starving the plant. The habit of shedding leaves on the advent of a period of drought is not confined to large trees like the Shimool alone. It is shared also by a class of small plants such as the Onion, *Rajanigandha*, etc., which have fleshy underground stems with the help of which they perenniate through the hard season defoliating all the aerial parts before its onset.

Leaf-fall is a characteristic of land-plants; it usually occurs at the commencement of the dry season (autumn). Old leaves are, as a rule, shed by all mesophytes, but some are *deciduous* (p. 68), remaining leafless for several months of the year, while others, like the Mango, shed their leaves only when the young leaves are unfolding, so that they are never *leafless*. Such plants are called *evergreens*. Leaf-fall is necessary for two reasons: (1) old leaves cannot transpire so rapidly as young leaves in spring, and (2) old leaves contain all the surplus mineral taken from the soil along with the transpiration current, and left in their cells by the loss of water, and these minerals are of no use to the plant. Deciduous leaves are thin, transluscent and smooth, and are generally broader and larger than those of evergreen plants, which are smaller, thicker and coarser.

XEROPHYTES.

Plants which live in hot, dry, sandy or desert places are specially adapted to dry conditions. They are called **Xerophytes.** They suffer, on the one hand, from a great deficiency of water-supply, and on the other, from the great dryness and heat of the atmosphere. Consequently, the most striking features of xerophytes are: (1) a very deep-seated and stout root-system and (2) a great reduction in surface of the shoot and the foliage, so that transpiration is adequately checked. The adaptations are :—

1. *Roots* are very long and deep-seated so that water may be absorbed from the moist sub-soil which is at a great depth (see p. 19).

2. The *stem* shows various modifications; it is never so long as in ordinary land-plants (mesophytes) but is generally greatly reduced and of a stunted form.

3. The *leaf* is the organ which suffers the greatest modification. Some xerophytes are entirely leafless or the leaves are reduced to spines or scales (*aphyllous*) and then the stem becomes flat, green and leaf-like (Cactii—Phani-monsa, fig. 120) carrying on the assimilating function of the leaf, or the branches become roundish and green cladodes (Asparagus—Satamuli, fig. 58). Others have arrested branch-shoots often with some of the leaves transformed into spines and the internodes undeveloped (Berberis—Daruharidra, p. 67). The reduction in the transpiring surface is often compensated for by corresponding thickness of the leaves; thus some xerophytes have small stiff leathery leaves (*sclerophyllous*) while others have thick succulent leaves (Bryophyllum—Pathur-kuchi, fig. 62, p. 43). Some of the leaf-succulent (*chylophyllous*) xerophytes have their leaves arranged in rosettes on an extremely abbreviated stem (*Agave*—fig. 36; *Aloe*—Gritakumari), so that the plants are often acaulescent (p. 31). Some xerophytes, like the Babla (Acacia), have pinnate leaves which have the power of automatically adjusting the transpiring surface by folding up more or less so that the leaf-surface is less exposed to direct light.

Xerophytes exhibit a wide range of forms, some approaching the ordinary mesophytes, others, like the Cactii, of a striking xerophytic form. The prevalent characters are (1) *spinescence* (as in Kantikary, Sheal-kanta, etc) and (2) *succulence* (Bryophyllum, Agave, etc).

Anatomically xerophytes are characterised by strong lignification. The wood is dense and hard, and the vessels

and cells of the xylem are narrow. This is correlated with the weakness of transpiration, and unfavourable conditions of growth. The arrested development of the branches and the leaves also gives rise to stiff and lignified terminations, such as thorns and spines. In the leaf the cuticle is very thick and the epidermal cells contain air. The stomata are sunk in the epidermis and lie entirely on the lower surface, so that loss of water is checked. Often there is an investment of hairs. The hairs are dead and

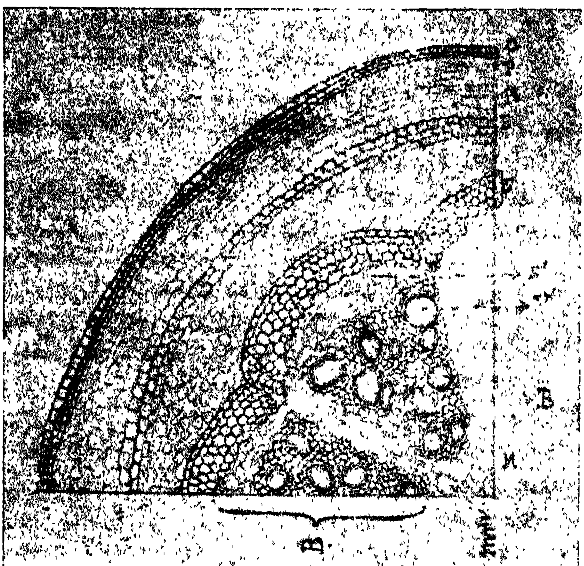


Fig. 406. Cross-section of Gulancha stem (one-fourth). C, periderm; p, phellogen; Pl, Cortex; E, endodermis; S, sclerenchyma; S', the soft bast of phloem, V, xylem vessels; B, bundles; M, medulla; mr, medullary rays.

contain only air, so that the wooly coat they form acts as a sun-shade and serves to prevent over-heating and to

reduce transpiration. The hairs are often found on the lower surface where the stomata lie. The upper surface may be quite smooth and even shiny, so that a great portion of the direct light falling on the leaf is reflected back. Cuticular transpiration is totally absent. Along with an increase in lignification, mechanical tissues such as sclerenchyma and bast preponderate in xerophytes, and parenchyma is correspondingly reduced. It is for this that plants living in desert or similar places are very hard and brittle, and possess stiff, spiny or prickly leaves and thorny branches.

In the mesophyll the palisade parenchyma is thicker than the spongy, and often the palisade tissue is formed in two or more tiers (see p. 236). The inter-cellular spaces are greatly reduced. On the whole, the tissues are more compact than in ordinary land plants. In the succulent forms *mucilage* abounds in some of the cells. The mucilage holds water tenaciously and is an adaptation to prevent loss of water and consequent drying.

CLIMBING PLANTS.

These may be classified into :—

1. *Root climbers* (see p. 26).

2. *Twiners* (see p. 38) which grow by throwing their axis spirally round supports by virtue of their transverse geotropism (p. 323).

3. *Scramblers* or stragglers (see p. 39) which are mostly shrubs or woody plants with long *straggling* branches and thorns, prickles, or hooks which are adaptations for climbing.

4. *Tendril-climbers* (p. 38) which include the majority of climbers. These may be.—

(*a*). *Leaf-climbers* where a part of the leaf acts as the tendril; *e.g.*, in Clematis and the Pitcher plant (*Nepenthes*) it is the petiole; in Gloriossa (fig. 103

it is the leaf-apex; in Smilax (p. 51) it is the stipule; in Pea (p. 41) it is the leaflets.

(*b*) *Stem-climbers* where a branch becomes a tendril as in the Cucumber family (p. 40).

The leaves of climbers are, as a rule, large, thin and broad. This is because they must have the widest exposure of their green tissues to light and air, for they have often to live in the shadow of the foliage of the plant over which they climb. As a result of twining torsions, most climbers have their stem twisted like cables or have a furrowed surface (Cucumber family). The wood of a climber is not compact and unbroken, as in the stem of a tree, but divided into isolated strands. The vessels too are very wide and large and form the greater part of the xylem. This is a safeguard against choking which will result from the twisting of the stem. The mechanical cells (fibrous tracheides) are replaced by wide vessels and tracheides, for the food matter must be carried over long distances in the extremely long stem which climbers form, but this is compensated for by the development of special strings of mechanical tissue outside the bundle in the cortex, or in the pith. In the Gulancha (*Tinospora cordifolia*), a cross-section of which is shown in fig. 406, the bundles are seen to be separate wedge-shaped structures each supported by a strong semi-lunar patch of sclerenchyma (see p. 272). The mechanical tissues are so arranged that they form very efficient girders for the support of the plant.

TEST-QUESTIONS.

Selected from University Calendars.

1. Describe the favourable conditions necessary for the germination of a seed, and the changes that take place in the seed during the process.

2. Describe from your own observation and contrast the germination of any Indian Dicot seed with that of a Monocot seed.

3. Give some idea of the main divisions into which the plant kingdom is divided. Define the divisions in a general way.

4. What are the functions of the root? Explain the structure and use of the root-cap and root-hairs.

5. What are the normal functions performed by roots? Show how the structure of the root is modified in relation to special functions.

6. State the distinguishing characters of root and of modified shoots.

7. Name and describe with examples the different kinds of underground stem met with in plants.

8. How can you distinguish between under-ground stem and root? Name the several varieties of under-ground stem giving Indian examples of each.

9. What are (*a*) tubers, (*b*) bulbs, (*c*) corms? Name plants which furnish examples of each of these.

10. Give an account of the various ways in which climbing plants attach themselves to their support.

11. What is venation and what are its principal forms. Illustrate your answer by sketches taken from Indian plants.

12. What is phyllotaxy? What are leaf-mosaic?

13. What are stipules and how may they be modified? Give examples.

14. Give the distinguishing characters of a raceme, spike, and spadix, illustrating your answers by Indian examples.

15. What are the evidences which show that the different parts of a flower are modified leaves?

16. Describe the microscopic structure of an anther and state how the pollen may be conveyed to the stigma of a flower.

17. Describe and sketch the various forms of ovules. What is the embryo-sac; Describe the changes that take place in it before fertilization.

18. What are the different methods by which pollination is effected?

19. What are pollen-grains? What is their function? Describe their microscopic appearance.

20. How do you recognise that a certain flower is a wind-pollinated flower. What are the advantages and disadvantages of this method of pollination?

21. What is the difference between pollination and fertilisation? State the different ways in which flowers are pollinated. Give examples.

22. Write what you know of the fruit of higher plants. Give Indian examples.

23. Describe in botanical terms the edible parts of the lichi, the fig, the pine-apple, the mango and the cocoanut.

24. Give a short account of methods of seed dispersion.

25. Describe from your own observation the various ways in which seeds are scattered. Of what importance is dispersion to the species?

26. Give a list with drawings of the common cell-contents.

27. What is the protoplasm? Where is it found in plants and what are its functions? How do you test for it?

28. What is cellulose? Where is it found in plants? What are its modification? How do you test for them?

29. Describe a typical vegetable cell illustrating your answer with diagram. Mention briefly the several ways in which vegetative cells multiply.

30. Draw diagrams of sections through the stem and the root of dicotyledonous plants which you have examined practically in the laboratory.

31. Compare the structure of the fibro-vascular bundles in the stem of (*a*) a Monocotyledon, (*b*) a Dicotyledon, and (*c*) a Fern.

32. Describe the process of cell-division.

33. Describe the structure of a typical stem just after secondary thickening has commenced.

34. Draw a diagram of the transverse sections of the young root of a dicotyledon. What are the functions of the different parts?

35. Describe the structure of the growing point of the root of a dicot plant.

36. Explain the formation of the ring-like markings in the wood of a dicotyledonous tree. Why are they absent in the stem of a monocotyledonous tree.

37. Describe the tissue elements which you observe in fibro-vascular bundles of a Dicotyledon.

38. Explain what is meant by the term 'annual ring' as applied to woody trees. Describe a 'ring' accurately and explain its formation.

39. Make a drawing to illustrate the tissues of a typical leaf. Name the parts and state their functions.

40. Describe the cellular tissues of a typical leaf. Give a sketch and mention the functions of the various kinds of cells shown in your sketch.

41. What are meristematic tissues? Where and how are they formed.

42. Describe the structure of lenticels and stomata. What is their functions? Describe the method by which this function is performed in both cases.

43. What is cork? How and why is it formed? Name Indian plants in which it occurs conspicuously.

44. What are starch-grains and where are they found? Describe their structure and mode of growth. By what micro-chemical tests may they be recognised?

45. How would you recognise under the microscope starch, cellulose, calcium carbonate and calcium oxalate?

46. Describe briefly how you would investigate the nature of elements necessary for plant-life by the water-culture method.

47. What is meant by irritability in plants? What manifestation of it occurs in nature? Of what use is it to plants?

48. How does the sap ascend through the plant? Trace the course of the tissues through which this process takes place—commencing from the roots and ending in the leaves.

49. Describe some methods by which you can demontrate the action of light on the formation of starch.

50. What is chlorophyll and what is its function? Enumerate the essential conditions under which assimilation takes place.

51. Why do plants transpire? Describe the principal organ of transpiration. Mention the conditions necessary for transpiration.

52. Give instances of the sensitiveness of plants to contact.

53. How is turgidity of cells produced and what part does it play in the growth of plants?

54. What is meant by transpiration? Describe any method by which you can determine the rate of transpiration.

55. Explain with reference to experiments the terms geotropism, hydrotropism and heliotropism.

56. Describe an experiment which proves that starch is manufactured in a leaf only when the leaf is exposed to sunlight.

57. How do green plants obtain their nitrogen?

58. Distinguish between assimilation and respiration and describe some simple experiments by which it can be proved that plants respire.

59. How does water enter and leave a plant? How are these events regulated? Mention the importance of water to plants.

60. How do plants obtain carbon? Enumerate some of the commonest substances found in plants which contain carbon.

61. Describe what happens in the fertilization of flowering plants after the arrival of the pollen on the stigma.

62. What happens to the water which plants absorb by their roots? Describe the structure of a stoma.

63. Distinguish clearly between a parasite and a saprophyte and explain how the latter obtains its nourishment. Give examples of each.

64. What is a parasite? Show how the phenomenon of parasitism is distinguished from epiphytism and saprophytism. Give examples of each.

65. Distinguish between paratonic, variation and spontaneous movements. Explain the terms; chemotropism, nutation, hyponasty, phototaxis, and irritability. Give examples.

66. What is growth? Mention the conditions essentially necessary for the purpose.

67. What do you understand by metabolism, chemotaxis, mycorhiza, enzymes, endosmosis, colloids, turgidity, and orthostichy?

68. Write a short essay on Rubiaceæ.

69. Define the orders : Solanaceæ and Labiateæ.

70. How do you distinguish between Rubiaceae and Compositæ. Give sketches,

71. How do you distinguish between Malvaceæ, and Solanaceæ. Give sketches.

72. Refer the following plants to their Natural orders and give reasons for your answer :—the Mustard, the Melon, the Tulsi, the Rice, the Cotton, the Fig, the Banana.

73. Compare the structure of the flower of a Pea with that of the flower of the Sensitive plant, and show why they are included in the same Natural order.

74. Describe the Natural order Cucurbitaceæ.

75. Describe the general characters of the Natural orders Labiateæ and Rubiaceæ.

76. How would you recognise a Leguminous plant? Describe briefly three Leguminous plants which are common in Bengal.

77. What do you understand by "alternation of generations" in the life-history of a plant? Illustrate your answer by reference to the normal course of life-history in Ferns.

78. In what respects does a Fern differ from a Dicotyledon?

79. Describe in detail the sporophyte generation in the Fern. Compare it with that of a flowering plant.

80. Give an account of the life-history of a Moss.

81. Compare the vegetative and reproductive structure of any Alga with that of any Fungus known to you.

82. What is the essential difference between Fungi and Algæ? Describe a Fungs and an Alga with which you are personally acquainted.

83. Compare the sexual reproductions in Spirogyra and Mucor.

84. Describe the structure and mode of development of Spirogyra.

85. Compare and contrast the modes of reproduction and nutrition in Mucor and Spirogyra.

86. What is Yeast? Describe its structure, life-history and mode of multiplication.

87. Give the outline of any modern system of classification with which you are acquainted.

88. In what ways do water-plants differ from land plants? Illustrate from your own observation.

89. Classify leaves and point out how their form is adapted to their function.

90. Write a short essay on vegetative reproduction among flowering plants, giving examples.

91. Describe the process which lead to the conversion of an ovule into a seed, and state what is the difference between albuminous and exalbuminous seeds.

92. Give a short summary of the various contrivances favouring the cross-fertilisation of flowers.

93. What do you understand by "alternation of generation"? Does this phenomenon occur among flowering plants?

94. Describe as fully as you can *any one* of the following families:—(*a*) Compositae, (*b*) Acanthaceae. (*c*) Graminaceae.

95. Give an account of the life-history, with special reference to the mode of reproduction, of any fungus you have examined.

96. What is respiration? Describe some simple experiment by which you can prove that plants breathe.

97. Describe the structure of the transverse section of a dicotyledonous stem in which secondary thickening has just commenced.

98. How does a plant take in food materials from the soil?

99. Describe the various parts of a leaf and give an account of the modifications they may undergo.

100. Give an account of the various contents of a growing cell.

101. What is meant by venation of leaves? Give an account of the parallel type of venation.

102. Give a comparative account of the inflorescences of the mustard, the wheat and the cocks-comb.

103. What is a fruit? How do you distinguish true fruits from spurious ones? Illustrate your answer by examples.

104. Give an account of the various modes of propagation of plants by means of roots and stems.

105. What are the normal functions of leaves? For what other purpose leaves may be utilised?

106. Distinguish between a root-hair and a root-let, as regards (a) structure and (b) function.

107. What do you understand by root-pressure? Describe some experiment by which you can demonstrate its existence.

108. Write short explanatory notes on the following botanical terms:—deliquescent, excurrent, zygomorphic, entomophilous, heliotropism, grafts, saprophytes, guard-cells, sieve-tubes, bordered pits.

109. What is an inflorescence? Describe the forms of racemose inflorescences that you are acquainted with.

110. Briefly describe the life-cycle of a Moss; and explain what you understand by "alternation of generations."

111. Describe the characteristics by which you recognise plants belonging to the Natural order Malvaceæ. Mention two plants of economic interest that belong to this order.

112. Give an account of the various plant members that are utilised as reservoirs of food.

113. Compare the fibro-vascular bundles in a monocoty-

ledonous stem with those in the rhizome of a fern, as regards distribution and structure.

115. What is bark? Describe its function and the manner of its formation.

116. Describe fully the inflorescence and the flowers of Wheat, and draw its floral diagram.

117. What do you understand by photo-synthesis? Describe some experiment by which you can demonstrate the products of this process.

118. Describe with examples the structure of hypogynous, perigynous and epigynous flowers.

119. How does a plant get rid of its waste products?

120. Write a short essay on the Asclepiadaceae.

121. Give an account of structures that exist in plants for defensive purposes.

122. How does the Yeast plant differ from a higher plant as regards its structure, general mode of life and reproduction?

123. Describe carefully the method of pollination of the Garden-Pea, illustrating your answer by figures.

124. Explain, by drawings and examples, the following terms: Scape, Caudex, Corm, Stolon, Cladode, Peltate leaf, Samara, Anatropus ovule, Siliqua and Sorosis.

125. What is understood by secondary growth? What is its significance? Describe the process as seen in the stem of a Dicotyledon.

126. Why are some plants able to keep their leaves during the winter, whilst others always lose them?

127. Describe the microscopical appearance of the transverse section of any Dicotyledonous stem that you have examined.

128. Describe briefly the various devices which enable plants to grow in (a) moist and (b) dry situations.

129. What are Stomata? Describe their structure and function.

130. What conditions are necessary for the formation of Chlorophyll? What is its use in plant growth? Is it invariably present in all plants?

131. Give an account of the typical forms of Indefinite Inflorescence, giving familiar examples in each case.

132. Describe the structure of an anatropous ovule and its development into the seed.

133. Define the Natural order Cyperaceae and Amaryllidaceae.

134. Describe the circulation of water through a plant. How is it caused and controlled?

135. Describe the various functions of normal or modified roots and give examples.

136. Describe the life-history of the Moss plant.

137. Explain the terms tetradynamous, thalamus, apogamy, anemophilous, saprophytic, epiphytic, xerophytic, and chromosome as applied in Botany.

138. Write a short essay on the Leguminosæ.

139. Describe the life-history of a moss. Of what significance are the two generations which it shows?

140. Discuss the importance of water-supply to plant life and briefly refer to the modifications of organs presented in a few water-plants found in the neighbourhood of Calcutta.

141. Describe the structure and life-history of a Desmid.

142. Describe experiments to prove the principal facts known about assimilation in plants.

143. Define the following terms with illustrative examples:—tetradynamous stamens, monadelphous andraecium, epicalyx, aril, papilionaceous corolla, capitulum, interpetiolar stipule, sinuous anther, staminode and glume.

144. How are the feeding processes in plants influenced by the alternation (*a*) of day and night and (b) of summer and winter?

145. Give the chief-characteristics of the Natural Order

Graminaceae and mention the plants of economic value.

146. Describe in detail the sporophyte of a fern.

147. What is bark? How is it formed? Describe the microscopic structure of a section, showing the typical formation of bark.

148. What do you understand by a classification of plants? On what characters does such a classification depend? Briefly describe any system of classification known to you.

149. In what different organs may plants store up supplies of food for future use? When, and in what ways, are these stores used up?

150. Describe the principal shapes of the lamina of a leaf. Give familiar examples.

151. Describe the microscopic structure of a cross-section of the stem of Indian corn.

152. What is intra-molecular respiration? Describe some experiment by which you can demonstrate this phenomenon. How does it differ from ordinary respiration?

153. Describe the various modes of insertion of the floral leaves on the thalamus. Give common examples.

154. What is yeast? Some yeast cells are put into a solution of sugar and kept in a warm place: describe the changes that may take place in (*a*) the yeast and (*b*) the solution.

155. Describe in detail the characteristics of the Natural Order Cucurbitaceæ. Name the economic plants.

156. Sketch the different parts of a leaf and show how they are fitted to do the different functions. How do you demonstrate that leaves manufacture carbohydrates?

157. What is a rhizome, and in what features does it differ from a root? Describe the mode of annual growth in length of the rhizome of any plant.

158. Give an account of the various kinds of corolla and mention the modes of pollination in any two of them.

APPENDIX I.

PRACTICAL MICROSCOPY.

The following instruments are required :—

1. *A Compound Microscope* with high and low power lenses.
2. *A Simple Lens*, for rough work.
3. *A Dissecting Case* containing—
   (*a*) *A Razor*, slightly hollow-ground.
   (*b*) *A Scalpel* or pen knife.
   (*c*) A pair of *Forceps, Brushes, Needles* and *Scissors.*
   (*d*) A few deep *Watch-Glasses*.
   (*e*) A few *Glass-Slides* and *Cover-Glasses*.
4. *Wash Bottles, Spirit Lamps* or gas burners, a few *Glass Basins* with cover, blotting papers cut into pieces 4 in. × 1 in. and packed in dozens, *Velvet Corks* or *Elder Pith* for sectioning.

The follow reagents are necessary.—

1. Glycerine; 2. Methylated spirit; 3. Iodine; 4. Chloro-zinc-Iodine; 5. Potash Solution; 6. Sulphuric Acid; 7. Aniline chloride; 8. Phloroglucine; 9. Hydrochloric and Acetic acids; and 10. a few stains, such as Fuchsin (Magenta), Eosin, Aniline blue, etc.

For observing the structure of protoplasm and the cell, scales of Onion, leaf of Vallisneria, aquatic roots, pollen-grains, hairs of Cucumber or of other stem may be taken and examined as described in Ch. XIII.

For observing the structure of cell-walls and their reactions—See Ch. XIV.

For studying the structure of the stem or the root, transverse and longitudinal sections are cut by means of a sharp razor. The stem or root is first thoroughly washed in water, then cut into small pieces to be conveniently held by the fingers, and the cut surface from which sections are to be taken is made perfectly smooth by means of a scalpel or a pen-knife. Materials preserved in spirit are preferable to fresh plants, for resins, gums and other matters present in fresh materials often stand in the way of getting good sections. For sectioning, the specimen is held with the fingers of the left hand with the smooth surface slightly projecting, and the razor is worked with the right hand. A sliding movement is given to the razor so that the

blade glides on the specimen from end to end. Only a gentle pressure, if at all, should be applied, and with practice, extremely thin sections can be obtained. On no account should the razor be used roughly or hurriedly or with force. The object is best secured by letting the blade glide smoothly on the specimen, no matter if full sections are coming out or not. Complete sections are often unnecessary. The surface of the specimen should be always kept moist with water or spirit. Some half a dozen or more sections should be cut at a time, the thicker or dirty ones are rejected, and the very best are picked up and placed in water contained in a watch-glass. Sections should never be allowed to dry up. The thicker sections sink in a short time while the thinner ones float longer. These are then carefully removed to another watch-glass containing water or the staining fluid, if necessary.

Leaves are rolled up into a compact cylinder, or folded several times to form a thick cushion, which is held firmly with fingers of the left hand and a part is cut off to get the smooth sectioning surface. The razor is then worked as detailed above.

The thin sections may then be at once mounted in a drop of Iodine solution on a glass slide, covered with a cover-glass, and observed under the low power of the microscope. The low power is often quite sufficient for ordinary purposes, the high power of the microscope is used only occasionally for observing details. The sections may also be mounted in Chloro-zinc-iodine, but the best mounting medium is Glycerine for it clears up a section very markedly. The sections may be left in strong Iodine sol. for sometime and then mounted in a drop of Glycerine and covered with a cover-glass. The method is the simplest and best of all and serves for all ordinary observations. Stained sections are prepared by putting them in 1 per cent solution of staining agents for some 5 min., and after thorough washing, first with water and then with spirit, they are mounted in Glycerine.

In mounting a preparation on the stage of the microscope great care should be taken to see that there is no moisture on the stage, and that no reagent or even water runs from the slide to the stage. The slide when ready for observation should be wiped quite dry at the free parts. Neglect on this point soon wears out the microscope, and good result can never be expected.

Iodine stains (1) lignified cells yellow, (2) suberised and cutinised cells brown, (3) protoplasm and proteids light yellow, (4) starch blue, and (5) cellulose scarcely at all.

Chlor-zinc-iodine, a mixture of Zinc chloride and Iodine dis-

solved in Potash-Iodide soln, gives almost the same reactions as Iodine but cellulose gives a violet colour, and starch grains swell up with it giving a blue mass.

Alcohol is a clearing reagent as it dissolves resinous and colouring matters, such as chlorophyll etc. It also hardens tissues.

Glycerine is a clearing and mounting medium.

Potash solution is a clearing agent. It dissolves all cell-contents and so makes a section transparent.

Sulphuric acid is used for swelling and dissolving cell walls. Also for hydrolysing cellulose into amylum and finally into sugar. See Chap. XIV.

Aniline chloride solution turns lignified walls deep yellow.

Phloroglucine solution (acid) turns lignified walls red. Fuchsin, Eosine, Aniline blue are staining reagents which stain the cell-walls and cell-contents variously.

APPENDIX II.

GLOSSARY.

Absciss-layer, a layer of separation formed at leaf-fall.

Acaulescent, stemless.

Accrescent, applied to parts of flower such as the calyx which increases in size after flowering.

Achene, a small seed-like dry indehiscent 1-celled, 1-seeded fruit.

Achlamydeous, used of flowering plants without calyx or corolla.

Acicular, needle-shaped.

Actinomorphic, applied to flowers which can be cut vertically into equal halves through two or more planes; that is, regular.

Adhesion, the union of parts normally separate.

Adnate, united or grown together.

Adventitious buds, buds produced out of their regular order.

Aestivation, the folding of the parts of a flower in the bud.

Aggregate fruit, formed from apocarpous ovaries of a single flower.

Alae, the two lateral wings of a papilionaceous corolla.

Albumen, any form of food-matter stored within the seed and about the embryo.

Aleurone-grains, nitrogenous food-matter stored in the reserve tissues of seeds.

Alga, a chlorophyll-containing class of Thallophytes.

Amphibious, plants which can live either in water or in the air.

Amplexicaul, leaf is one which clasps the stem so as to surround it.

Amylum, starch.

Anatomy, the internal structure of plants.

Anatropous, applied to an ovule which is inverted, not straight.

Andraecium, the collective term for the stamens of a flower.

Anemophilous, or wind-pollinated.

Annulus, a row of cells around the sporangium by the contraction of which the sporangium bursts and spores are scattered.

Anther, the part of a stamen which contains pollen.

Anthocyanin, a coloured pigment found in the cell-sap of the coloured parts of plants, in flowers, fruits, foliage.

Antipodal cells, a group of three cells at the chalazal end of the embryo-sac of Angiosperms.

Apetalae, without petals; another name of the Incompletæ.

Apocarpous, when the carpels of a gynoecium are separate and free.

Apophysis, a swelling under the base of the theca in some mosses.

Archegonium, the flask-shaped female sexual organ in higher cryptogams with neck canal-cells and a venter containing an egg-cell.

Archesporium, a group of cells from which spore mother-cells are produced.

Aril, an investment to a seed which arises after fertilisation.

Asci, a kind of tubular sporangium in certain fungi containing eight spores called ascospores.

Assimilation, process of building up sugar, starch and other matters by the protoplasm.

Auriculate, leaf with ear-shaped projections at base.

Autogamy, self-pollination.

Awn, a bristle-like appendage, especially in the glumes of grasses.

Bark, the outer dead covering tissue of thick stems or roots.

Basidium, a cell from which spores or conidia are produced by abstriction; formed in the mushrooms.

Bast, special tissue in the plant-body consisting of the Phloem and prosenchymatous cells.

Berry, a fleshy succulent fruit with homogeneous pulp.

Bilabiate, two-lipped, said of a flower.

Bract, a leaf subtending a flower.

Bud, the unexpanded young part of a foliar and flowering shoot.

Bulb, a form of underground shoot with fleshy scale-leaves in which food-material is stored.

Bulbil, a deciduous bud, usually formed on an aerial part of a plant.

Callus, thick pad of dense protein matter formed in old sieve-tubes.

Calyptra, the hood on the sporogonium of a moss.

Calyx, the outer whorl of a flower consisting of sepals.

Cambium, a layer of tissue formed between the wood and the bark.

Campylotropous, said of an ovule which is bent like the letter U.

Capitulum, a cluster of sessile flowers condensed on a flat receptacle.

Capsule, a dry dehiscent fruit.

Carpel, the female ovuliferous leaf of the flower.

Caruncle, tumers or ridges on the surface of the seed-coat.

Caryopsis, dry indehiscent 1-seeded fruit of grass-family.

Catkin, a deciduous spike bearing flowers of one sex only, usually male.

Caudex, an unbranced stem as of Palms.

Caulescent, having a stem rising above the ground.

Cauline, appertaining to the stem.

Cell, the structural unit of which plants are built up.

Cell-membrane, the cell-wall.

Cell-plate, used of aggregates of cells in one plane.

Cell-sap, the watery fluid contained in a cell.

Cellulose, the essential constituent of cell-walls composed of a carbo-hydrate.

Centrifugal, used to such inflorescences as open their flowers from the centre outwards ; definite inflorescences.

Centripetal, used to such inflorescences as open their flowers from outside inwards ; indefinite flat-topped inflorescences.

Chalazogamic, applied to fertilisation taking place by the pollen-tube entering the embryo-sac by way of the chalaza and not by the micropyle.

Chlorenchyma, a green chlorophyll-containing tissue.

Chlorophyll, the ordinary green pigments of plants which help carbon-assimilation, present in chloroplasts.

Cilia, delicate protoplasmic filaments serving as organs of locomotion in certain swimming cells.

Cladodes, flat leaf-like stem or its branches.

Claw, a name given to the stalk of petal.

Cleistogamic,—ous, applied to inconspicuous flowers which do not open and are self-pollinated.

Collective fruit, consists usually of the perianth-leaves, bracts, as well as the ovaries of several flowers, commonly of all the flowers of an inflorescence united into one. They are all succulent.

Collenchyma, a form of mechanical tissue having prism-shaped cells whose angles are much thickened.

Columella, the sterile tissue in the centre of the sporogonium of Moss around which the spore-layer is formed.

Cone, the crowded scales bearing ovules or pollen-sacs in Gymnosperms.

Conjugation, the union of two gametes or sexual cells resulting in a zygote ; a process of sexual union in Algæ and Fungi.

Contorted, used when the corolla is spirally twisted in bud.

Convolute, a leaf which is rolled up longitudinally in the bud.

Cordate, heart-shaped.

Corm, a form of fleshy underground stem like a large bud with scale-leaves.

Corolla, aggregate of petals, the coloured leaves of a flower.

Corona, a kind of ligular structure on petals.

Cortex, the portion of stem and root external to the vascular tissues.

Corymb, a flat-topped inflorescence of the indefinite type.

Crenate, tooth-shaped; said of the margin of a leaf.

Cross-fertilisation fertilisation of the ovules of one flower by the pollen from another flower.

Cross-pollination, the deposition on a stigma of pollen brought from another flower.

Cruciferous, shaped like a cross, said of a flower.

Cryptogamia, or non-flowering plants which do not show up their sexual organs.

Cuticle, a layer on the surface of a plant formed of the cutinized outer surfaces of the epidermal cells.

Cystolith, a concretion of calcium carbonate deposited on peculiar peg-shaped structures in the epidermal cells of the leaf of Ficus family.

Cytoplasm, the protoplasmic body of a cell as opposed to the nucleus.

Daughter-cells, cells which arise from the division of any cell.

Deciduous, not permanent; said of leaves and the perianth.

Decurrent, said of a leaf when the lamina adheres to and runs down the stem so as to make it winged.

Decussate, applied to leaves which are arranged in pairs alternately crossing each other at right angles at successive tiers.

Dehiscence, the mode of opening of a fruit, anther, spore-capsule etc.

Dermatogen, the embryonic cellular layer at the apex of stem or root which develops the epidermis.

Dextrorse, used of twining plants which make a clock-wise movement, from left to right.

Diastase, an enzyme or ferment which converts starch into sugar.

Dichogamy, the maturing of pollen and stigma in a hermaphrodite flower at different times to prevent self-fertilisation.

Dicotyledon, plant with two seed-leaves or cotyledons.

Didynamous, having four stamens, two short and two long.

Dioecious, unisexual, the male and female flowers being on separate individuals.

Divergence, applied to the angle between the insertion of successive leaves on a stem.

Dormant buds, are those which arise in the leaf-axils in the usual way but which do not forthwith expand into shoots. They remain often many years until stimulated into activity by some special event.

Drupe, succulent fruit with hard stony endocarp enclosing a single seed.

Ducts, canals formed by the fusion of a row of cells.

Ectoplasm, the hyaline outermost layer of protoplasm in a cell.

Egg-cell or ovum, the female generative cell.

Embryo-sac, the large cell in the nucellus of an ovule, in which

the egg-cell and ultimately the embryo arises.

Endoplasm, the soft inner granular protoplasm of a cell.

Endosmosis, the transmission of fluids through porous membranes from the exterior to the interior.

Endosperm, the tissue which grows within the embryo-sac of flowering plants after fertilisation and which is stored with food-materials for the embryo.

Endospore, asexual reproductive cell formed within sporangia.

Entire, untoothed ; said of the margin of a leaf.

Entomophilous, insect-pollinated.

Enzyme, ferments found in seeds, etc., as diastase, pepsin.

Ephemeral, short-lived.

Epicotyl, the part of a seedling plant above the cotyledons.

Epidermis, the outermost layer of cells in a plant body.

Epigeal, growing above the ground.

Epiphytes, plants growing attached to other plants (ærial).

Equitant, leaves folded lengthwise and sitting astride one another.

Ethereal oils, formed in cells of odoriferous plants.

Evolute, turned back.

Exosmosis, the transmission of fluids through a porous membrane from the interior to the exterior.

Extine, the outer coat of a pollen-grain or spore.

Extrorse, applied to such anthers as open towards the outer whorls of a flower.

Eye, an undeveloped bud on the surface of a tuber.

Fascicle, dense cluster of flowers, leaves, roots etc.

Ferment, a substance produced by the protoplasm which induces chemical changes.

Fertilisation, the process by which the pollen reaches and acts upon the ovule finally uniting the male and female plasmas.

Fibrous layer, the thickened portion of the anther-wall which brings about dehiscence.

Filament, the stalk of an anther.

Filiform, thread like.

Fimbricate, fringed by fine sub-divisions of the margin.

Flagellum, the whip-like filament of protoplasm which serves to move the cell about.

Floret, the single small flower amidst a cluster of flowers in a compact inflorescence.

Flowering-glume, the outer of the two chaffy scales provided with awn which enclose the flower of graminaceæ.

Follicle, a 1-carpel dehiscent fruit opening by the ventral suture.

Foot, the sucker by which a young fern plant is attached to the prothallium and draws nutriment.

Fungus, a cellular cryptogam having no chlorophyll.

Funicle, the stalk of an ovule or seed.

Fusiform, spindle-shaped, tapering both ways from the middle.

Galeate, helmet-shaped.

Gametangia, cells from which gametes are developed.

Gamete, a sexual cell.

Geitonogamy, crossing between separate neighbouring flowers growing on the same plant.

Gemma, a small undeveloped bud.

Gemmation, the act of budding.

Generative cell, the cell in pollen-grains which ultimately fertilises the egg-cell.

Genetic spiral, the spiral line passing through the points of insertion of successive leaves on the stem.

Genus, an assemblage of very nearly allied species of plants.

Geotropism, the tendency of plants to grow towards the earth.

Germination, the process by which the embryo of a seed grows up into a young plant.

Glabrous, smooth, without hairs.

Glandular, bearing glands or like a gland.

Globoid, the tiny mass of phosphate of magnesium and calcium often found in aleurone-grains.

Glomerule, a cymose inflorescence, formed into a head.

Glumes, the chaff, bract like scale on the inflorescence of graminaceæ.

Gynoecium, the carpel of a flower or all the carpels collectively.

Gynophore, the stalk-like internode supporting the gynœcium only.

Habit, the general appearance of a plant.

Habitat, geographical position or residence of a plant.

Hastate, dart-shaped or like an arrow-head.

Haulm, the stalk of a grass of any kind.

Haustoria, the sucking root of a parasite, or similar food-absorbing organs.

Helicoid, one-sided cyme coiled circinnately.

Herkogamous, where self-pollination is prevented by suitable contrivances in homogamous flowers.

Hermaphrodite, flowers with both stamens and pistil.

Heterogamous, bearing two kinds of flowers which differ sexually.

Heterophyllous, bearing leaves of more than one form on the stem.

Heterosporous, having spores of different kinds, especially male and female.

Heterostyled, where the styles and stamens of a flower are of different lengths.

Hilum, (1) of strach grains : the centre around which the stratifications are deposited ; (2) of a seed : the scar left at the point of attachment of the seed when it falls off.

Hirsute, having rather coarse or stiff hairs.

Homogamous, bearing only one kind of flower, either male or female ; also when both the sexes in a flower mature at the same time.

Homosporous, having spores of similar kind.

Humus, a soil composed of decaying and rotten vegetal matter.

Hyaline, transparent like jelly.

Hybrid, a plant resulting from the cross-breed of two different species.

Hydrophytes, plants which live in water.

Hydrotropism, the particular irritability of the roots of plants to grow and move towards moisture.

Hymenium, the spore-bearing surface of a fungal receptacle.

Hyphæ, the filaments of the thallus of a fungus.

Hypocotyl, the part of a stem below the cotyledons.

Hypocrateriform, salver-shaped ; used of a corolla with a long tube and expanded flat limbs.

Hypogeal, underground ; said of the cotyledons during germination.

Hypogynous, used of a flower when the sepals, petals and stamens are inserted on the thalamus below the ovary.

Imbricate, overlapping like the scales of a fish.

Imparipinnate, pinnate with a terminal leaflet.

Incised, cut irregularly and sharply.

Indehiscent, not opening, said of fruits.

Indusium, the scaly outgrowth of a fern leaf enveloping the sorus.

Inferior, lower or below ; said of the members of a flower.

Inferior ovary, where the ovary is adnate to the calyx tube and the sepals become epigynous.

Inferior calyx, where the calyx is free from the ovary which is superior.

Inflated, bladdery.

Inflorescence, the actual cluster of flowers or their mode of arrangement in the flower-bearing part of a plant.

Infundibuliform, funnel-shaped, said of a gamopetalous corolla.

Innate or basifixed, where filament is attached to the base of an anther.

Insectivorous plants, are those which catch insects and absorb their juice.

Integument, the outer coatings or envelopes of an ovule.

Internode, the portion of a stem between the nodes or the points of insertion of leaves.

Intine, the inner layer of the wall of the pollen-grain.

Introrse, said of an anther dehiscing towards the centre of the flower.

Intussusception, a method of growth of the cell-wall whereby new particles are inserted between those already present.

Involucre, a circle of bracts surrounding a dense cluster of flowers.

Involute, rolled inwards; said of a leaf in bud.

Isogamy, sexual union between two equivalent gametes, found in Algæ and Fungi.

Labellum, a peculiar floral leaf in the flower of Canna family.

Lamella, a thin plate as in the gills of Mushrooms.

Lanceolate, lance-shaped; said of a leaf.

Latex, the milky, white or coloured, plant-juice.

Laticiferous, containing latex.

Leaf-axil, angle between leaf-base and stem.

Legume, the dehiscent fruit of Pea family; monocarpellary and breaking into 2 valves.

Lichen, an organism consisting of some algae and fungi living together in a life-partnership to their mutual benefit.

Lignin, the substance present in the walls of woody cells which make them hard.

Ligule, the thin scaly outgrowths of the leaf-sheath of grasses; a tongue-like projection.

Ligulate, tongue-like; said of certain flattened flowers of compositæ.

Liverwort, the lower family of plants under the Bryophytes.

Lodicules, tiny scales, usually two in number, which represent the perianth in the minute flowers of the grass-family.

Loment, a transversely constricted legume which breaks up into 1-seeded parts, as in Acacia family.

Macrospores, opposed to microspores, the large (female) spore of heterosporous plants; in phanerogams it is the embryo-sac.

Medulla, the pith or central parenchyma of the stele.

Mericarp, one of the two seed-like parts into which a schizocarp breaks up.

Meristem, embryonic tissue found at all growing parts of plants.

Mesophyll, the parenchymatous ground tissue of a leaf.

Metabolism, the chemical changes which take place in a living active protoplasm; it may be either a constructive process when it is called anabolism, or a destructive process called catabolism.

Micropyle, the opening in the integuments of an ovule through which

the pollen tube passes to the embryo-sac.

Microspores, opposed to macrospores, the smaller (male) spores of heterosporous plants ; in phanerogams, the pollen grains.

Monadelphous, of one brotherhood ; used of stamens when they are all united together by their filaments alone to form a tube.

Monandrous, with one stamen.

Moniliform, like a necklace or string of beads.

Monocarpellary, consisting of but one carpel.

Monocotyledonous, having only a single-cotyledon or seed-leaf.

Monoecious, having male and female flowers on the same individual plant ; opposed to dioecious.

Morphology, the science of forms ; that department of Botany which deals with the forms alone of the plant-body, excluding its development, functions, etc.

Mycelium, the filamentous vegetative body of a fungus which ramifies in the substratum on which the fungus lives.

Mycorhiza, a root invested by a mantle of fungal threads which behave like root-hairs ; a case of symbiosis in many forest-trees.

Nectary, a honey-secreting gland or a honey-sac in a flower.

Neuter flowers, those without stamens and carpels.

Node, part of a stem at which a leaf is inserted.

Nucellus, the tissue of the ovule inside its coats which contains the embryo-sac.

Nuclear plate, the plate of chromosomes which forms in the middle of a nuclear spindle when the nucleus is dividing.

Nucleus, a specialised part of the protoplasm which acts as its organic centre, guiding, directing, controlling its whole activity.

Nut, a hard indehiscent 1-seeded fruit resulting from a polycarpellary ovary.

Nutation, spontaneous changes in position of all growing organs.

Obovate, inversely ovate i.e., the broader end at the apex.

Ooplasm, the female plasma.

Oospore, a fertilised egg-cell.

Operculum, the lid of a Moss capsule.

Order, a group of nearly allied genera related to one another by structural characters common to all.

Orthostichies, vertical ranks of leaves on the stem.

Orthotropous, vertical ovule with micropyle, nucellus, chalaza, and funicle all lying in a straight line.

Osmosis, the phenomenon of liquid diffusion through a porous membrane such as cell-wall.

Ovary, the swollen part of the pistil containing the ovules.

Ovule, the rudiment of the seed being the macrosporangium, containing the single macrospore, the embryo-sac.

Ovuliferous, bearing ovules.

Palea, the chaff-like bracts of grass-flowers—and of the compositæ.

Palisade-cells, the upper green cylindrical cells of the mesophyll of a dorsi-ventral leaf differentiated from the lower spongy cells owing to difference in illumination of the two sides.

Palmate, radiate like the fingers of the outstretched palm.

Panicle, a compound loosely much-branched inflorescence.

Papilionaceous, like a butterfly; applied to the flower of the Pea family.

Pappus, a hairy or feathery development of the calyx-segments of plants of the sunflower family; which promote dispersion of the tiny seed-like fruits.

Paraphyses, sterile filaments accompanying the sexual organs in mosses or the asci, basidia, and other fertile cells of many fungi.

Parasite, a plant which lives upon and obtains nutriment from the tissues of a living plant.

Parastichies, secondary spiral lines formed by crowded leaves on a short axis, as in pine-apple or pine-cone.

Parenchyma, thin-walled soft tissue of a plant.

Pedate leaf, one like the claw of a bird.

Pedicel, the stalk of a single flower, as opposed to peduncle.

Peduncle, the primary flower-stalk supporting either a flower-cluster or a solitary flower.

Peltate, shield-like; said of leaves when the petiole is attached to the under-surface of the blade and not to the margin.

Perennial, lasting year after year.

Perfect flower, having all the ordinary organs of a flower.

Perfoliate, a leaf appearing as if perforated by the stem.

Perianth, applied to floral leaves especially when it is not easy to distinguish calyx and corolla.

Periblem, the embryonic tissue of the primary meristem of the growing apex from which the primary cortex arises.

Pericarp, the wall of the mature carpel or their fruit.

Perichaetium, the whorl of leaves at the top of the Moss stem which form a flower-like structure, enveloping the archegonia and antheridia.

Perigynous, around the ovary and not at its base, said of a flower.

Perisperm, the tissue of the nucellus of the ovule outside the embryo-

sac in which food matter is stored for the future use of the embyro.

Peristome, the ring of teeth around the mouth of a Moss capsule.

Perithecium, the flask-shaped cavity in which asci are produced in certain fungi.

Personate, said of an irregular 2-lipped corolla with the throat closed by a projection of the lower lip.

Petal, a corolla-leaf.

Petiole, the stalk of a leaf.

Phanerogamia, flowering plants, plants which show male and female organs.

Phloem, the soft outer tissue of a vascular bundle containing mainly sieve-tubes and companion cells which carry assimilated matter.

Phyllode, a flattened petiole assuming the form and function of a leaf-blade.

Phyllotaxis, leaf arrangement; order of distribution of leaves on the stem.

Pinnate leaf, a compound leaf with leaflets arranged on either side of a common rachis or petiole.

Pinnati-fid,-partite,-sect, said of the marginal incisions of a simple leaf according as it is slightly cut or deeply parted or almost divided.

Pistil, the female organ of a flower consisting of an ovary, stigma and style (which may be absent).

Pistillate, said of a female flower (which has no stamens).

Pitcher, a tubular or excavated leaf or rather petiole containing a liquid ; pitcher plants are insectivorous.

Pith, the medulla or central cellular tissue of a stem or root.

Pits, thin plates on a thickened cell-wall.

Pitted cell, cells marked by many pits.

Placenta, the part of the carpel or ovary which bears the ovules ; in ferns, the part of the leaf tissue which bears the sporangia.

Plicate, plaited, folded lengthwise into plaites.

Plumule, the first bud or rudimentary shoot of an embryo.

Pod, a dry dehiscent elongated fruit, a legume.

Pollen, the male spores or cells contained in the anther.

Pollen-tube, the tube produced by the pollen grain on germination on stigma which carries the male plasma in it.

Pollination, pollen arriving at a mature stigma for germination.

Pollinia, masses of coherent pollen grains ; singular :—pollinium.

Polyadelphous, said of stamens which form many bundles of filaments, the anthers being all free.

Polycarpellary, having or consisting of a number of carpels.

Polypetalous, Polysepalous, having free petals or sepals, as opposed to gamopetalous, gamosepalous.

Pome, a kind of fleshy fruit of which the Apple and Pear are types.

Porous, used of dehiscene of anthers and fruits etc., by means of pores or small holes.

Prickle, a sharp-pointed process of the epidermis which may be easily pulled out.

Protandrous, flowers which mature their anthers before the stigma, opposed to

Protogynous, flowers which mature their stigma before the anthers.

Proteid, Protein, a series of nitrogenous matters of complex composition produced by the protoplasm.

Prothallus, the structure produced by the germination of the spore which bears the sexual organs.

Protonema, filaments produced by the germination of moss spores from which the leafy moss plant arises by budding.

Protoplasm, the living substance of plants and animals.

Pulvinus, an enlarged tissue at the base of a petiole at its point of insertion on the stem ; found in the Leguminosæ.

Pubescent, covered with soft down-like hairs.

Pyrenoids, refractive bodies imbedded in the chlorophyll of certain green algæ, especially of conjugatæ.

Raceme, an indefinite inflorescence with a long axis and pedicelled flowers. **Racemose,** in racemes, or like a raceme.

Rachis, the main axis of an indefinite inflorescence or of a compound leaf.

Radical, belonging to or arising from a root or the subterranean portion of the stem.

Radicle, the rudimentary root of an embryo.

Raphe, the ridge of an anatropous ovule which represents the part of the funicle adnate to the ovule.

Rayflorets, the marginal flowers of a dense head of flowers.

Receptacle of a flower, the short or flattened axis upon which the various floral members are inserted ; the thalamus.

Reniform, kidney-shaped.

Repand, slightly wavy or undulating.

Replum, the persistent frame-work of the placenta which remains behind in some cruciferous fruits after the valves have fallen away.

Resin-duct, an inter-cellular passage into which resin is secreted and stored.

Respiration, or breathing, a process by which the plant takes in

oxygen from the air and gives out carbon dioxide and moisture, exactly as in animals; by this process the plant keeps itself warm and fit to carry out nutritive functions.

Reticulate, in the form of network.

Revolute, rolled backward from the margins.

Rhizoids, hair-like filaments of lower plants which act like roots.

Rhizome, underground creeping stem usually rooting at the nodes and becoming erect at the growing end.

Rib, a vein of a leaf.

Ringent, gaping, said of a bilabiate corolla.

Root-cap, the cellular tissue forming a cap-like mantle at the apex of a root.

Root-stock, same as rhizome.

Rotate, wheel-shaped; said of a regular gamopetalous corolla with circular and spreading limbs.

Runner, a filiform prostrate branch running on the ground and rooting at the nodes.

Saccate, sac-shaped; bag-like.

Sagittate, arrow-shaped, said of a leaf with two basal lobes turned downwards.

Samara, an indehiscent winged fruit.

Saprophyte, a plant which grows on dead and decaying organic matter

Scape, a peduncle of an acaulescent plant bearing flowers.

Scarious, thin, dry and membranous.

Scorpioid, said of cymose inflorescence which has flowers on alternate sides on a false axis.

Schizocarp, a fruit which breaks up into 1-seeded parts.

Sclerotic cells, hard thick-walled stone-cells of irregular form.

Scutellum, the peculiar cotyledon of the embryo of grass family.

Seed, the fertilised and matured ovule containing the embryo.

Sepals, the first or outer green leaves of a flower.

Septate, divided by partition walls. **Septum,** a partition wall.

Septicidal, dehiscence of capsule taking place through the splitting up of the septa of the ovary.

Serrate, like the teeth of a saw. **Serrulate,** finely serrate.

Sessile, without stalk, said of a leaf or flower.

Seta, the stalk of the spore-capsule of a Moss.

Sheath, a tubular envelope.

Sieve-Plate, the area or portion of the wall of a sieve-tube perforated by fine pits.

Sieve-tube, the most important tissue of the phloem, consisting of

elongated articulated cells communicating with each other by means of numerous pits in their common walls.

Silicula, a short indehiscent siliqua.

Siliqua, the dehiscent fruit of the Mustard family, characterised by the persistent placenta called replum.

Sinistrorse, used of twining stem which turn from right to left.

Sorus, a cluster of sporangia.

Spadix, a fleshy spike.

Spathe, a large bract-leaf sheathing a spike or spadix.

Species, all individuals of common ancestry and similar vegetative and floral characters; the unit of classification.

Spermatoplasm, the male sexual plasma.

Spermatozoid, ciliated male sexual cells of lower plants.

Spike, an indefinite inflorescence with sessile flowers on a long rachis.

Spine, a sharp-pointed body arising from or forming a part of a leaf.

Spore, a reproductive cell which is detached from the parent and develops a new individual separately.

Sporangium, a spore-sac or spore-case. Sporangiophore, the stalk of a sporangium.

Sporogonium, the spore-capsule of mosses.

Sporophyte, that stage in the life cycle of a plant which bears spores; also spore-bearing plants, as opposed to seed-bearing plants.

Spur, a hollow sac-like part of flower used as a nectary.

Stamen, the male organ of a flower producing the male spores called pollen. **Staminode**, a sterile stamen, a filament without anther.

Standard, the upper large petal of a papilionaceous flower.

Sterigma, the tubular cell from which conidia are abstricted, found in fungi.

Stigma, that portion of a pistil which receives the pollen.

Stipe, the stalk-like suppott of the ovary Stipitate, having a stipe.

Stipules, paired foliaceous appendage or the leaf-base.

Stolon, a short procumbent stem with buds rooting at short intervals and producing aerial shoots.

Stoma, an epidermal pore through which plants communicate with the air, bounded by two special cells called guard-cells which regulate the opening.

Style, the stalk-like prolongation of the ovary upon which is formed the stigma.

Sucker, branch shoot arising from a subterranean base

Suspensor, the row of cells produced by the fertilised ovum at the end of which the embryo arises.

Swarmspore,, motile, ciliated, naked asexual reproductive cells of lower plants.

Symbiosis, an association of two organisms living in intimate connection, both contributing to their mutual advantage ; a life-partnership.

Sympodial, having the axis formed of several branch axes.

Syncarpous, (pistil) made up of two or more united carpels.

Synergidae, two naked cells situated along with the egg-cell at the micropylar end of the embryo-sac, and assisting in the passage of the male cell of the pollen-tube to the egg-cell.

Syngenesious, stamens with anthers united and filaments free.

Tendril, a filamentous organ borne on the stem which is sensitive to contact and by means of which a plant climbs.

Tentacle, an irritable hair or emergence of a leaf, with or without a glandular tip, which is highly sensitive to contact.

Ternate, used of compound leaves with three leaflets, one terminal and two lateral.

Testa, the integument of a seed, often arising from the outer of the two coats of the ovule.

Tetradynamous, used of stamens when there are six of which four are longer than the other two.

Thalamus, the floral receptacle bearing the floral members.

Thallus, an undifferentiated vegetative body without showing any distinction of its parts as members.

Thalloid, of the nature of a thallus.

Tissue, an aggregate of cells having the same origin, development, structure and function.

Tomentose, covered with a dense outgrowth of woody hairs.

Torus, the thalamus of the flower ; also the thickening on the membrane of cell-wall which bounds a bordered pit.

Tracheides, elongated thick-walled lignified water-conducting cells of plants.

Transpiration, the act of giving out aqueous vapour from the foliage of a plant.

Truncate, appearing as if with the head or tip cut off.

Tuber, a thickened subterranean branch or stem with numerous small buds, called eyes, on the surface.

Tubercle, a small tuber-like excrescence on the stem.

Tunicated, having concentric coats or covering layers.

Turgidity, Turgescence, the state of tension set up within a cell owing to endosmotic pressure of the vacuolar sap upon the elastic cell-wall.

Umbel, an indefinite inflorescence in which the flower stalks arise all

from the same point. **Umbelliform**, like an umbel.

Unguiculate, clawed ; like a claw ; said of petals.

Unisexual, of one sex, containing either the male or the female organ.

Urceolate, urn-shaped ; i.e., hollow and swollen but contracted near the mouth.

Utricle, a small one-seeded fruit with a loose inflated bladdery pericarp ; any small bladder-like body.

Vacuole, the cavity inside the protoplasm containing the cell-sap.

Valvate, in æstivation, the arrangement of the leaves in bud when they just touch each other by the margins but do not overlap.

Valve, the pieces into which a capsule breaks up ; the flaps in a dehiscing anther.

Valvular, opening by valves, said of dehiscence of fruits.

Vascular, pertaining to vessels or ducts.

Vascular bundle, the long conducting tissues of plants carrying both raw and assimilated food matter.

Veins, the strands of vascular bundles found in leaves.

Venation, the arrangement or mode of distribution of veins in a leaf.

Ventral, belonging to the inner face of an organ.

Vernation, the arrangement of leaves in a bud.

Versatile, said of an anther attached by a point at its middle to the filament, so as to be able to turn freely on all sides.

Verticillate, whorled, said of leaves arising from the same node.

Vessel, a row of long cells fused so that the transverse walls are absorbed so as to form a long continuous tube.

Villous, bearing long and soft hairs.

Viscid, glutinous, sticky, often said of a ripe stigma.

Whorl, arrangement of leaves arising in a circle round the stem or axis.

Wing, a membranous expansion on the surface of fruits, seeds etc ; also the lateral petals of a papilionaceous corolla on which the bee usually alights.

Wood, the hard lignified portion of the vascular portion of a plant.

Xenogamy, pollination between flowers growing on different individuals of the same species.

Xylem, the woody portion of the vascular bundle.

Zygomorphic, irregular flowers capable of division into two equal and similar halves along only one plane of symmetry.

Zygospore, a spore formed by the union of two similar gametes.

Zygote, same as zygospore, sometimes extended to include also the oospore.

APPENDIX III.

NAMES OF PLANTS

mentioned in the Book with their Botanical and Vernacular synonyms.

The name of the plants as mentioned in the book is given first in bold type; (bot) *indicates the Botanical name*; (h) *Hindusthani*, (b) *Bengali*, (m) *Marhatti*, (g) *Gujrati*, (bom) *Bombay*, (k) *Kanarese*, (t) *Tamil*, (te) *Telugu, and* (s) *Sanskrit.*

Acacia,—See Babla.

Aconite (e), Aconitum ferox (bot), Kat-bish (b), Bachneg (m), Vashanavi (t), Vashnabhi (k), shingadio Vachnag (g).

Agave Americana (bot), The Century plant (e), Rakas patta (d), Kantala (h), Murga or Bilati Ananash (bom), Pithakalabuntha (t), Kakasimatalu (te), Junglikunva (g), Bhuttale budukattalenari (k).

Akanda (b), Calotropis Gigantea (bot), Madar (h), Arkam (m), Erukku (t), Yekka, yokàda (k), Jilledu, mandaramu (te), Akado, akdamu jhada (g).

Alkooshy lota, See Cuscuta.

Amada (b), Curcuma Amada (bot), the Mango-ginger (e), Am-huldi (h), Amba-halada (m), Miamidi-allum (te), Kajura gauri (bom).

Amra (b), Spondias mangifera (bot), Ambara (h), Amralak (s) Kuttuma (t), Hog-plum (e).

Amherstia nobilis, an imported plant now cultivated in the gardens for its beautiful bunch of flowers.

Amrool-shak (b), Oxalis Corniculata (bot), Chukirka, Amboli (h), Puli-Chuitaku (te), Puliyavi (t), The Indian Sorrel (e), Bhiu-sarpati (bom), Pullam purachi sappu (k).

Antirrhinum majus (bot), the Snap-dragon (e).

Apang (b), Achyranthes aspera (bot), Lal-jira, Chirchira (h), Apamarga (s), Aghada (bom), Apamargamu (te), Mayurivi (t), Kutri (g), Utrani (k), Prickly Chaff-flower (e).

Aparajita (b), Clitoria ternatea (bot), Dintana (te), Kakka-namkodi (t), Kajali, gokaran (bom), Vishnu Karanti (h), Gokar-namuly Vishnu (k).

Aroid or **Arum,**—See Kuchoo.

Asoka (b), Saraca indica (bot), Asogy (h), Asogam (t), Ashunkur (k), Jassoondi, asoka (bom).

Asparagus,—See Satamuli.
Ata,—See Custard-apple.

Babla (b), Acacia arabiaca (bot), Babla (h), Nallatumma, Tumma-chettu (te), Karu-Veylam (t), Babhul (m), Kalikikar (dec).

Bael (b), Aegle Marmelos (bot), Bilva (s), Bel Sriphal (h), Bil, Bila (m), Beli (t), Maredu, Vilva-pandu (te), Bila-patri (k).

Bag-bharenda (b), Jatropha Curcus (bot), Jangli-arandi, safedind, (h), Aadivi amudamu, nepalam (te,) Kattamanaku (t), Yerand, jepal (bom), Magali-eranda (m).

Baikul (c.p), Gymnosporia Montana (bot), Gaja-chinni (c.p), Danti, hedda-chintu (te), Zekadi (bom), Talkar, Kharai (punj), Kakra (m), Kingari (h).

Bakash (b), Adhatoda Vasica (bot) Arusha (h), Addasaram (te), Addtodai (t), Malabar nut (e), adulasa (bom).

Bakphul (b), Sesbenia grandiflora (bot), Agasta (bom), Agati t), Avisi (te), Agase (k), Basna (h).

Balsam (e), Impatiens Balsamina (bot), Dopaty (b), Gulmendi (h), Kundalu-Kola (s.i), Terada (bom).

Bamboo (e), Bambusa (of several species) Bans (h&b).

Banana (e), Musa paradisiaca (bot), Kala, (b), Kela (h), Monz, Kel (m), Vazhaip pazham, Valai (t), Arati, Kadalamu (te), Bale, Bale-naru (k).

Bara-pana (b), See Pana.

Barbaty (b), Vigna catjang (bot), Rajamasha (s), Lobiya, raish (h), Chowlai (m), Caramunny-pyre (t), Boberlu, alu-sundi (te) Alasandi, Tada-gumy (k).

Basil,—See Toolsy.

Belphul (b), Jasminum Sambac (bot), Mallika, Mugra (h), Mullippa (t), Mogri, (bom), Mullige (k).

Bena (b), Andropogon muricatus (bot), Khus-Khus (h), Vettiver (t), Kuruveru (te), Usir (s), Vala (m), Vala (g), Lavancha (k).

Berala (b), Sida cordifolia (bot), Kharati, Bariar (h), Chickna (m), Chiribena, tettagurachettu (te).

Berberis asiatica or Berberis aristata (bot), Daruharidra (b), Darhold, rasvat, Kashmal (h).

Betel plant (e), Piper Betle (bot), Tambula (s), Pan (b,h,) vettilee (t), Tamal-pakoo (te), Nagavela (bom).

Bhoi Champa (b), Kaempferia rotunda (bot), **Bhucham** pakamu (te), Kondakalava (t), Bhumichampak (s).

Bhuban-bilasy lata (b) Bougainvillea spectabilis (bot).

Bhela (b), Semecarpous anacardium (bot), Jeedivithulu (te), Shenkottai (t), the Marking-nut tree (e), Bhela (h), Bibba (bom), Bhiamu (g).

Bichuty (b), Fleuria interrupta (bot), Barhanta (h).

Bija-Sal (b), Pterocarpous marsupium (bot), Bija, peet-shola (h), Bibla, huni (bom), Kandamiruga-mirattam (t), Gandumrugam-nettura, peddagi (te).

Brinjal (e), Solanum Melongena (bot), Begoon (b), Baigun (h), Wangi (dec), Kuthire kai (t), Venga-chiri-Vangu (te), Vange (bom).

Brownea Hybrida, an American plant introduced and cultivated in our gardens.

Bryophyllum (e), Bryophyllum calycinum (bot), Pathurkuchi (b), Kop-pata (b), Malaikali (t), Simajamadu (te), Ahiravan-Mahiravan (bom).

Bullock's heart (e) Anona reticulata (bot), Nona, (b) Louna, Ram-phal (h), Ramphal, Ram-sita, Ramsitu-plam (t,te)

Cajuput tree (e), Melaleuca leucadendron (bot), Kayaputi (h), Kijapute (t), Kayakuti (bom).

Candy-tuft (e), Iberis (several species), a cultivated showy winter annual of the gardens.

Canna (e), Canna indica (bot), Sarvajaya, Savjaya (h), Krishnatamara (t), the Indian shot (e), Kullveler-mami (t), Devakeli, Kandali (m).

Castor oil plant, See Ricinus.

Cape Gooseberry, See Tepari.

Carrot (e), Daucus carota (bot), Gajara (h&b), Maujal-mullangi (t), Pitakanda (te).

Chal-kumra (b), Beniucasa cerifera (bot), Petha, Gol-koddu (h), Kohala (m). Bhuru-kolu (g), Kohala (bom), Kalyana-pushinik-kay (t), Pendli-gumaddi-kaya (te), The white melon (e).

Chalta (b), Dillenia indica (bot), Chilta (h), Mothe Karamala, Karambel (bom), Uva (t), Uva, pedda (te).

Champak (b), Michelia Champaka (bot), Sampagni-puvvu (te), Shampang (t), Sampagehuvon (k), Champa, Champaka, Swarna-Champa or Sona-chapha (b,h,m).

Chandra-mallika (b), Chrysanthemum indicum (bot), Gul-daoody (h), Chamimti (te).

Chattim (b), Alstonia scholaris (bot), Chatim, Satwan, Satni (h), Aedakularitchettu (te), Shampang, Wodrase (t), Janthala, Mudhol, (k).

Chitra or **Chitrika** (b), Plumbago zeylanica (bot), Agni-sikha, Chitraka (s), Venchitti (t); Tella-chitra (te), Chitrak (bom).

China-badam,—See ground-nut.

Chola (b), Cicer arietinum (bot), Channa (h), Senagalloo (te). Chick-Pea (e), Kadalai (t).

Cinnamon (e), Cinnamonun zeylanicum (bot), Dalchini (b&h), Tarruwa (t), Sanalingu (te).

Clematis, a garden climber.

Cocoa-nut Palm (e), Cocos nucifera (bot), Narikel (b), Nariyel (h), Narel (g), Mahad (m), Tenna, tengr (t), Narikadam, tenkaia (te), Tengina (k).

Cock's Comb (e), Celosia cristata (bot), Morugphul (b), Mayura-Sikha (s), Kokan, murghka (h), Kodi-juttu-tola-kura (te).

Colocasia (bot),—See Kuchoo.

Coral plant (e), Jatropha multifida (bot), a native of South America, cultivated and naturalised in Indian gardens.

Crinum (bot).—See Sookhdarshan.

Crotons (e), Codieum variegatum (bot), of which there are numerous varieties.

Cucumber (e), Cucumis sativus (bot), Shasha (b), Khira (h), Muhevchri (t), Dozakaia (te), Kakdi (m), Sante Kayi (k).

Cuscuta (e), Cuscuta reflexa (bot), Alkooshy lata or Swarnalata (b), Amarbeli (b), Poonaikkall (t), Dodder (e), Paniyanaku (te), Sitamma-popu-nulu, Akashwel (m).

Custard apple (e), Anona squamosa (bot), Ata (b), Sharifa, Ata Sitaphal (h,g,m), Sita-palam, Sita-pazham (t), Sitapandu (te).

Daruharidra (b).—See Berberis asiatica.

Date (e), Phœnix dactylifera (bot), Khajur, Kharjure, or Kharjura in every province.

Datura (e), Datura strammonium (bot), Ummetta Dhaturamu (te), Umattai (t), Thorn-apple (e).

Dhau (h), Woodfordia floribunda (bot), Dhataki (s), Dhai, Dhanla, Santha (h), Dhamati, Dhooshi (bom), Serinji (te), Phulsatti (m).

Dhenras (b), Hibiscus esculentus (bot), Lady's finger (e), Bhindi, Ramtoroi (h), Bhenda (bom), vendack-kay, Vendi (t), Penda, bendakaya (te).

Dillenia (bot),—See Chalta.

Dodder (e),—See Cuscuta.

Devdaru (b), Polyalthia longifolia (bot), Asok, Asoka, Asuphal, Devadari, Deodar, in all the provinces, Assothi (t).

Doomoor (b), Ficus glomerata (bot), Gular Paroa (h), Umbar (bom), Umbara (m,g), Atti (t,te).

Drono (b), Leonorus sibiricus (bot), Gumma (h), Enugutummi (te), Kamba (m), The Indian fig (e).

Dundul (b), Luffa ægyptiaca (bot), Nuni-beerd (te), Ghiaturai (h), Ghosali (bom), Turai (g).

Durba (b), Cynodon dactylon (bot), Creeping panic grass (e), Duba (h), Durva (m), Arugampilla (t), Ghericha (te).

Gaj-pippul (b), Scindapsus officinalis (bot), Bari-pipli (h), Enuga pippalu (t), Atti-tippli (t). Motto pipper (g), Thora pimple (m).

Gandharaj (b), Gardenia florida (bot).

Ganja (b), Cannabis indica (bot), Ganjayi (te), Kanja (t), Indian hemp (e), Bhang (h,m), Ganja-ched (t), Ganjari Chettu (te).

Garjan (b), Dipterocarpus turbinatus (bot), Gurjan in all the provinces.

Garlic (e), Allium sativum (bot), Rasun (b), Lasun (h), Vellulli (t,te), Bellulli (k).

Genda,—See Marigold.

Ghentu (b), Clerodendron infortunatum (bot), Bhant (h), Barangi (Punj), Bakauda (te).

Ginger (e), Zingiber officinalis (bot), Ada (b), Adrak (h), Ale (m), Adu (g), Shakku-inji (t), Sonti, allum (te).

Glory-lily (e), Gloriosa superba (bot), Ulat chandal or Bishalanguli (b), Carrihari (h), Agnisikha (te), Kartikka-Kishanghu (te), Nagakaria (m).

Gold-mohur (e), Cæsalpinnia pulcherrima (bot), Khrishna-Chura (b).

Gol-murich (b), Piper Nigrum (bot), Miryalu (te), Melagu (t), Black pepper (e), Golmarich (h), kalamiri (bom), Kali-marich (m).

Gourd [e], Cucurbita maxima [bot], Mitha Kaddu [h], Suphara Kumra [b], Pushinikkay [t], Gummadi kaya [te].

Grape [e], Vitis vinifera [bot], Angur [b,h], Driksha param [t], Mantri-param [te], Draksha-phalam [s], Drakh [g].

Grita-Kumari [b], Aloe [e].

Ground-nut [e], Arachis hypogea [bot], China Badam [b], Mung-phali [h]. Bhui-shing [bom], Bhui-Chana [g], Verkadlai [t], Verusanagalu [te].

Guava [e], Psidium guava [bot], Amrut [h]. Piyra [b], Segapu [t], Jama koia [te], Tambada-pera [bom].

Gulancha [b], Tinospora cordifolia [bot], Gulvel [bom], Gulavela [m], Shindil kodi [t], Tippa-lige Guluchi [te].

Hanseraj [b], Hedychium coronarium [bot].

Hasna-hena [b], Cestrum nocturnum [bot].

Hatisoor [b], Heliotropium indicum [bot], Hattajuri [h], Bhurundi [m], Hathisundhani [g], Nakkipot, Tetkodduki [t], Nagadanti [te].

Henna, See Menthi.

Higli-badam [b], Anacardium [bot], Kaju [h], Jædimamidi [te], Mundirikai [t], Cashwe-nut [e].

Hingcha [b], Enhydra fluctuans [bot], Hurhuch [h], Marsh-herb [e], Himlochika [s].

Hogla [b], Typha elephantina [bot], The Elephant grass [e], Eraka [s], Pater Rambana [h], Rambana [m], Ghabajarin [g], Jammugaddi [te].

Hog-plum [e], Spondias mangifera [bot], Amrataka [s]. Ambodha [h], Amra [b], Katmaa [t], Aravimamadi [te], Jangli-am [bom].

Haldi [h], Curcuma longa [bot], Halud [b], Pasupa [te], Manjal [t], Turmeric [e], Halede [m], Halada [g].

Hul-Kusha [b], Leucas aspera [bot], Chotapalkusa [h], Tamba (bom), Tumbai obedi [t], Tamma-chettu [te].

Hurhuriya [b], Gynandropsis pentaphylla (bot), Jangli-hurhur (h), Velakura, vaminta (te), Nayvæli (t) Tilavana (m), Arkapushpika (s).

Indian hemp, —See Ganja.

Indian Soap-nut (e), Sapindus trifoliatus (bot), Ritha (b,h), Arishta (s), arithe (g), Punnango (t), Kukudu (te).

Indigo (e), Indigofera tinctoria (bot), Nil (h,b), Averi (t), Neelie (te), Nilguli (bom).

Jack-fruit (e). Artocarpous integrifolia (bot), Katiahar (h), Panasha (te), Phanas (m, bom), Pilapazhand (t).

Jam (b), **Jamoon** (h), Eugenia jambolana (bot), Naval (t). The Black plum (e,) Kala-Jam (b), Nasoda (te), Jambul (bom), Jambura (g).

Jamrul (b), Eugenia malaccensis (bot).

Jarul (b), Lagerstroemia flos-regina (bot), Taman (bom), Mota bon (m), kadali (t), Chennangi (te).

Jasmines,—See Jui.

Java (b), Hibiscus rosa-sinensis (bot), The shoe flower (e), Jaustnuphul (g), Jasund (h), Shappathuppu (t), Javapushpamu (te), Jasvan (m).

Jayphal (b,h.), Croton Tiglium (bot), Nutmeg (e), Jamalgota (h,m), Napal (g), Nervalam (t), Nepalavitna (te).

Jhinga (b), Luffa acutangula (bot), Torui (h,) Peekunkai (t), Beerkai (te), Shirola (m,) Turia (g).

Jhumkolota,—see Passion flower.

Jujube,— See Kool.

Jui, (b), Jasminum Sambac (bot), Juthi, Juthika, Ambusta (s),

Kabra (h), Capparis spinosa (bot), Kabra, Ber, in many provinces; Kabar (bom).

Kuchoo (b), Colocasia antiquorum (bot), Aroids (e), Arvi (h), Chama kuru (te), Shima-ikilangu (t), Kasalu (m).

Kadamba (b,h), Anthocephalous kadamba (bot), . kadamba (m,b,h,bom), vellai kadamba (t), Rudraksha-kamba (te).

Kalkashinda or **kasonda** (b), Cassia occidentalis (bot), kasunda (h), Kasinda (te), Payavirai (t), Hikal (bom), Kusundro (guz).

Kala Jam,—See Jam.

Kala-Jira (b), Nigella sativa (bot).

Kalmegh (b), Andrographis paniculata (bot), Kiryat, Mahtila (h), Bhunimba (s), Olenkirayat (m), Kariyatu (g), Nilavembu (t,te).

Kanchan (b), Bauhinia acuminata, B. tomentosa (bot), Kanchnar (h). Kanchani (t,te), Apta (m), Asundro (g).

Kalmi-Shak (b), Ipomoea reptans, I. aquatica (bot), Karenbu (h), Nari (Punj), Nalichi baji (bom), Koilangu (t), Tuti-kura (te).

Kanak-Champa (h), Pterosperum acerifolium (bot), Mooch kunda, Karnikara (s), Matsakauda (te).

Kanchira (b), Commelina benghalensis (bot), kanuraka (h).

Kanta Natya (b), Amarantus spinosus (bot), Kantamiris, Lal-shag (h), Mulluk-kirai (t), Nullu-tota keora (te).

Kanthal (b)—See Jack-fruit.

Kantali Champa (b), Artabotrys odoratissima (bot).

Kantikary (b), Solanum xanthocarpum (bot), Kantæli (h), Nela-Mulka (te), Kandankattiri (t), Kuda (te) Bhuringni (bom), Van-Nellagulla (k).

Karavy (b), Nerium odorum (bot), Kaner, Kanoity (h), Ganneru (te), Kanaveerum (t).

Karamcha (b), Carissa Carandas (bot), Kantakreji, Karoda (h), Kanugohettu (te), Kanhera (bom), Hoyamara (m).

Karela (h), Momordica Charantia (bot), Uchay (b), kakarchettu (te), Povakkj (t), Karla (bom).

Kath-Bæl (b), Feronia Elephantum (bot), Wood-apple (e), Kapitha (s), Kat-Bel, Kawat, (m), Kotha (g), Vallanga, Kavit, (t), Belada (k), Villam (mad).

Kea or **Ketuky** (b), Pandanus odoratissimus (bot), Kebra, Ketgi (h), Mogalaichettu (te), Talamchedi (t), Screw Pine (e), Kenda (bom), Keoda (m), Kewoda (g).

Kham aloo (b), Dioscorea alata (bot).

Khirui (b), Euphorbia thymifolia (bot), Dudhi (h), Patcha-arise (t), Biduru-nana-hiyyam (te), Nayeti (bom), Mathi-dudhi (m).

Khurbooj (b), Cucumis Melo (bot), Musk melon (e), khurbuz (h), Mulam or Velapandu (t), Chibunda (m), Vellari-verai, Velapatam (te).

Kool (b), Zizyphus Jujube (bot), Ber, Bayer (h), Jujube (e), Badari (s), Reugha, Regi, Rega-panda (te), Yellande (t), Yelchi (k).

Koosh or **Kash** (b), Poa cynosuroides (bot), Duv (h), Durva (s).

Koonch (b), Abrus precatorious (bot), Gunja (s), Rutti, Gumchi (h), Gurijenza (te), Gundumani (t), Gumchi (g).

Kokshim (b), Vernonia cinerea (bot), Sahadevi (s), Sira-shengalanir (t), Moti Sadori (bom).

Krishna-Chura (b), Caesalpinnia pulcherrima (bot), Ratnagandi (k).

Krishna-kali (b), Mirabilis Jalapa (bot), Four o'clock plant (e), Sandhya rag (s), Chandra-kantha (te).

Kuchila or Nirmali (b), Strychnos Nux-vomica (bot), The strychnine plant, Kuklah (dec), Ettikkottai (t), Mushtivittulu (te), Kanni-rak-kuru (s. i.) Kajra (bom).

Kulia khara (b), Hygrophila spinosa (bot), Gokshura, Talmakhana (h), Nirguri-veru, Neerugobbi (te), Neeramulli (t), Talima-khana, Kolasunda (m), Gokhuru (g), Kalavan Kabija (k).

Kushum (b), Carthamus tinctorius (bot), Safflower (e), Barre, Kar (u.p). Kushumbha, Kurdai (bom), Sendugram (t), Agnisikha (te).

Lal-bharenda (b), Jatropha gossypifolia, J. glandulifera (bot), Jungli-eranda (h), Addalay (t), Nela- amida (te), Totla-gida (k).

Lajjabatty lota (b). Mimosa pudica (bot), Lajalu (h), Murugadu-maramu (te), Thottalpadi (t), The Sensitive plant (e), Lajri (m).

Lalpata (b), Euphorbia pulcherrima (bot).

Latkan (b) Bixa Orellana (bot), Kisri, Kesari, Shendri (m, (bom), Jupharachettu, Jafra-vitullu-chetty, (te), Jaframaram (t), Gowpurgee (h).

Lataphatki,—See Naphatki.

Lau (b). Lagenaria vulgaris (bot), Alabu (s), Shora-kai (t), Anapa-kai (te), Hunea-kuddu (dec).

Lavanga (b), Eugenia caryophyllaea (bot).

Lemon (e), Citrus Limonum (bot), Jambira (h), Gora Nebu (b), Meta or Motu limbu (g), Thorla-limbu (m), Periya-elumichampazam (t), Pedda-nimma-pandu (t),

Litchi (e), Nephelium Litchi (bot), Lichu, Nichoo (b), Lichee (h).

Lotus (b) Nelumbium speciosum (bot), Kamal, Padma, Uptal (s), Kanwal (h), Tavarigadde (k), Tamarai, ambal (t), Erra-tamara veru (te).

Lunka (b), Capsicum frutescens (bot), Lal-marich (h), Mirapakaya (te), Malaghay (t), Red cayenne pepper (e), Mirchi (g), Menashina kayi (k).

Madhabilata (b), Hiptage Madablota (bot), Madheolata (h), Madhabi (s), Madhumalati (m), Madhavi tige, Vadla yarala, potu-vedla (te).

Makal (b), Trichosanthes palmata (bot), Lal-indrayan, (h), Kaundal (bom), Koratti, Shavari-pazham (te), Avvaguda-pandu (te).

Makhan shim (b), Canavalia ensiformis (bot).

Mallika (b),—See Bel.

Man-kachoo (b), Alocasia indica (bot), Mankundu (h), Manaka (s), Alu (m).

Mango (e), Mangifera Indica (bot), Amra (s), Am, manga maram, maa, mangas (t), Makandamu (te), Ambanujhada (g).

Mansa, Mansa sij (b), Euphorbia nerifolia (bot), Jhohar (h), Akujimudu (te), Yale kalli (k), Nivadanga (m), Sehunda (s).

Marigold (e), Tagetes patula (bot), Genda (b).

Marsilia,—See Shoosny-Shak.

Mash-kalai (b), Phaseolus mungo *var.* radiatus (bot) Urid (h), Udid (m), Adad, Arad (g), Patchaypyre (t), Minu-mulu, patsapetsalu (te), Hasam (k).

Masur (b), Lens esculenta (bot).

Melon (e), Citrullus vulgaris (bot), Tarbuj (h), Turmooj (b), Pitcha-pullam (t).

Menthi (h b) Lawsonia innermis (*var.* alba) (bot) Moruthonri (t), Kuravamu (te), Henna (e), Marutonri, Aivanam (t), Gunuta-chettoo (te).

Mina lobata,—a small cultivated twining herb.

Mooch-kunda,—See Kanakchampa.

Moog (b), Phaseolus mungo (bot), Mung (h), Mug, Mag (bom), Puchapayru (t), Wuthulu patcha-pessra (te), Hesaru-bela (k).

Moon-flower (e), Ipomoea bona-nux (bot), Ital-kalmi, Dudiya-kulmi, Kalmilata (b.h.) Gulchandni (bom), Naga-mughatei (t), Nagara-mukutty Kai (te), Chandrakant, Ban-bauri (h).

Moola (h), Raphanus sativus (bot), Murai (h), Mullangi (te,t), Radish (e).

Mukta-jhuri (b), Acalypha indica (bot). Swet basanta (b), Kuppi, Khokali (h), Khokli (m), Vanchi kanto (g), Kuppaimeni (t), Kuppai-chettu (te), Chalmari (k).

Mulberry (e),—See Toont.

Munjeet (b) Rubia cordifolia (bot) Tamravalli (te), Manchilta (t), The Indian madder (e), well-known as the Manjit or Munjeestha.

Musoor-chana (b), Lathyrus Aphaca (bot), Jungli matar, Masur-chana (b,h).

Mustard (e), Brassica juncea (bot), Sarisa (b), Sarson, Rai (h), Sasiva (c), Kaduka (Mal.), Kadugu (t), Avalu (te), Sharswapa (s).

Nag-phani (b),—See Phani-mansa.

Nasturtium (e), Tropaeolum majus (bot), a common small garden annual.

Naphatki (b), Cardiospermum Halicacabum (bot), Jyotishmati (s), Lataphatky, Sibjhul (b), Karolio (g), Kanphuti, Naphat (bom), Muda-oottan (t), Wallagulisienda, Kanakaia (te).

Natiya-shag (b), Amarantus blitum *var.* oleracea (bot), Chobrai (h), Mullukiroi (t), Kontemat (te).

Naravelia zeylanica (bot), Chagalbati (b), Murcha.

Nayantara (b), Vinca rosea (bot), Sadapul (m), Billaganeru (te), Sadamallige, Kempu Kasiganagilu (k), The Rose Periwinkle; a west Indian plant now cultivated in Indian gardens.

Neem (b,h), Melia Azadirachta (bot), Vepa (te). Vempu (t), The Neem or Margosa tree.

Nerium odorum,—See Karavy.

Nishinda (b), Vitex negando (bot), Sambhalu, Nirghundi (h), Tellavavilli, Siddhuvarumu (te), Noch-chi, Chinduvaram (t), Nirgundi (s), Katri (bom), Lingoor (m), The Chaste Tree (e).

Nooni-shak (b), Portulaca oleracea (bot), Looni-shak (b), Khursa, Kurfa, muncha, munya (h), Lunia, Lonak (g), Parpukire, parupu (t), pavili-kura (te).

Nul-lota (b), Thunbergia grandiflora (bot), Meel-lota (h); a beautiful fence-climber with large blue flowers.

Okra (b), Urena lobata (bot), Bona-venda, Ran-tupkada, wagdan bhendi (m), Villiak (k).

Ol (b,h), Amorphophallus campanulatus (bot), Jangli-suran, Zamin-kand (h), Suran (m), Karu-naik-kizhangu or Karunakalang (t), Kanda-godda, poti konda (te).

Onion (e),—Allium Cepa (bot), Piyaz (h), Dungari (g), Kanda (m), Vella Vengazam (t), Niruli (te).

Opuntia Dillenii,—See Phani Mansa.
Oxalis (e).—See Amrool-shak.

Palas (b,h), Butea frondosa (bot), Muttuga-thoras or-mara (k), Palasham (t), The Bastard Teak, The Forest flame (e), Dhak, Faras, Kaukeri, Chichra (h), Chiula, puroha (bom), Khakar, paras (m,g), Moduga, mohatu, paladulu (te).

Pan (b), Piper Betle (bot), Nagavella (bom), Vettilæ (t), Betel leaf pepper (e), Tamal-pakoo (te), Pan (generally).

Pana (b), Pistia Stratiotes (bot), Jal-kumbhi (h), Antaritamara (te), Agasa-tamara (t), Prashni, Gondala (m), the Wester-lettuce (e).

Pani-amla (b), Flacourtia cataphracta (bot), Paniyala (b), Talispatri (h,t, te), Jaggam, Jan-gama, Tamban (bom).

Pani-marich (b), Polygonum serrulatum (bot).

Pani-phal (b), Trapa bispinosa (bot), Singhara (h,t), Sringataka (s), The Water Chest-nut (e), Parigadda (te), Shingoda (g), Shingada (m).

Papaya (e), Carica papaya (bot), Papita (h), Boppayi (te), The Tree Papaw (e), Perangi (k), Papia (g), Pappayi or pappali (t).

Parijat, Palita madar (b), Erythrina indica (bot), Indian coral tree (e), Pangra, panjira (h), Muruka-marum (t), Modugu (te), pangara (m).

Parul (b), Stereospermum suaveolens (bot), Paral, parur (h), Patali (s), Padal, pahad (bom), Padri (t), patali (te), Kalagori (m), Pandri (c.p.).

Passion flower (e), Passiflora fœtida (bot), Jhumko-lata (b), the wild species; the garden species is Passiflora palmata which has large flowers with a beautiful fringe of corona inside the petals.

Pathur-kuchi (b),—See Bryophyllum.

Patol (b), Trichosanthes dioica (bot), Palwal (h,h), Adavipotla (te), Peyu-padal (t), Snake gourd (e).

Pea (e), Pisum sativum (bot), Kabli Matar (b), Patani (t), Gunducanagalu (te), Batani (k).

Phani-mansa (b), Opuntia Dillenii (bot,) Nagphana (h,b), Nagatali (t), the Prickly Pear (e), Naga-mulla (te), Naga-dali (t), Chappal-send (dec).

Pine-apple (e), Ananassa sativa (bot), Anaras (b).

Pipul (b), Piper longum (bot), Pippali-kattee or-chittee (te), Pippili (t), Long peeper (e).

Pistia (e),—See Pana.

Podina (h,b,t, te), Mentha arvensis (bot), The Marsh Mint (e).

Portulaca, (e),—See Nooni-shak.

Pumpkin (e) Cucurbita pepo (bot), Kumra (b), Kalyanpucuni (t), Bubi-kumbala (k).

Rajanigandha (b), Polyanthes tuberosa (bot), Gool-shubbo (h).

Rangan (b), Ixora coccinea (bot), Loha Jhangia (h), Panku (m), Bakora, abuli (bom), Patali (s), Cetti (t), Kepala Kisgara (k),

Rasna (b,m,g), Vanda Roxburghii (bot), Nai (b), Vanda (b), Veddi (t), Kanapa-chettu badanike, neardan (te).

Red-pepper—(e), See Lunka.

Red Santal-wood (e), Pterocarpus Santalinus (bot), Rakta-chandan (s), lal-chandan (h,b), Erragandha-puchekka (te), Shenshandanuum (t), Kempu gandha (k).

Reta or **Reetha** (b), Somecarpus Anacardium (bot), The Marking nut tree (e), Bhela (h,b), Bhilavan (dec), Shenkottai (t), Tidi-vittulu (te), Bibba (bom).

Ricinus communis (bot), the Castor-oil plant (e), Endi (h), Rerhi, Eranda (b,s), Amanakku (t), Amudala (te), Haralu, Andla (k).

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Sajina, Shajna (b,h), Moringa pterygosporma (bot), Munaga (te), Murangai (t), Horse-radish tree (e), Munga-cha (m).

Sakarkand aloo (b), Ipomoea Batatas (bot), The Sweet potato (e), Ranga alu (b), Vullii-kiz-hangu (t), Chelagada (t), Sakaria (g).

Sal, Shal (b,h), Shorea robusta (bot), Aswakarna (s), Epachettu (te), Kungitium (t).

Saptaparni (s), Alstonia scholaris (bot), Chattim (b), Satni, Chattni (h), Ezhilaippalai, Wodrase (t), Edakula-pala, palagaruda (te), Kodale, Madale, Kadusale (k).

Satamuli (b), Asparagus racemosus (bot), Sadabori, Shadavari (t,te), Shakakul (h), Satawar, Satavari (g,m).

Screw pine—See Ketuky.

Sensitive plant,—See Lajiabaty lota.

Shalook (b), (red and white), Nymphæa Lotus (bot), Kambal (s), Nilofar (h), Allikada alli-tamara (te), Vellumbai Ambal. (t), Water-lily (e), Kanval, Kamal (g, m).

Sheakool (b), Zizyphus Oenoplia, (bot), Shrigal-koli (s), Ghainthi or goithi (m).

Shealkanta (b), Argemone mexicana (bot), Pila Dhatura (h), Brahma-dandi (s,te). Kudeyoethi (t), Feringi-dhutra (m), Brahmadanti (mal).

Shephalika (b), Nyctanthes Arbor-tristes (bot), Seuli (b), Harsinghar (h), Pagadamalle (te), Manjapu-meru (t), Night Jasmine (e), Partak (bom).

Shimul (b) Bombax malabaricum (bot), Silk-cotton tree (e), Shimal (h), Mundla-buraga-chettu (te). Pula, mulilaum (t).

Shola (b). Aeschynomene aspera (bot).

Shoosny-shak (b), Marsilia quadrifoliota (bot), Chick-lita kura (te),

Shun (b), Crotolaria juncea (bot), San, Son (s,h) Jenapanara (te), Sanabu, (k), Janab-ka-nar (bom).

Shwet Sarisa (b), Brassica alba (bot), Suffed-rai (h) Sidharatha (s) White mustard (e).

Sisoo (b), Dalbergia Sissoo (bot), Shingshapa (s), Sisma, Sisu (h), Nukku-kattai, Zetta (t), Sissukarra (te).

Soondali (b), Cassia Fistula (bot), The Indian Laburnum, (e), Sonhali (h), Raelachettu, Reylu, Suvarnam, (te), Kouraih-kay, Kone (t), Kakee (k) Bahaya, baya (m), Garmal, Sarmal (g).

Sthal-padma (b), Hibiscus mutabilis (bot), Pudmacharinee (s), Hinaparchi (h), The Changeable Rose (e).

Sukhdarshan (b), Crinum asiaticum (bot), Chindar, kanwal, pandar, (h), Kesarichetta (te), Nagdamani (g), Nagdavana (m), Visha-mungali (t).

Sun-flower (e), Helianthus annuus (bot), Surjamukhi (b,h), Surja-kanti (t,te), Hottutirugana (k).

Swarnalata (b), See Cuscuta.

Tal (b), Borassus flabelliformis (bot), Tal, tad (h), Tali (s,k), Panai (t), Tati (te).

Tamarind (b), Tamarindus indica (bot), Tintiri, Amlika (s), Amli, Imli (h), Tentul (b), Amli, Chintaz (bom), Poolie (t), Chinta-Chettu (te), Karangi (k).

Teak (e), Teotona grandis (bot), Shagoon (b). Saka (s), Sagun (h), Tekku, Tek (t), Sagwan, Sag (bom), Teginamara, Saguvani-mara (k), Teku (te).

Tej-pata (e), Laurus malabaricum (bot), Jhal-patra, Talispatra, Tejpatra (s).

Telakucha (b), Cephalandra indica (bot), Vimba (s), Tondla or Bimbi (bom), Karai (t), Bhimb, Kandmi-ka-bel (h), Tonde Balli (k). Ghobe, Gluru, Galedu (g).

Tepari (b), Physalis peruviana (bot), The Cape gooseberry (e), Bondula (k), Mottampuli (t,te).

Thulkury (b), Hydrocotyle asiatica (bot), Vallarei (t), Manduka-brummi, Babassa (te), Brahman manduki, Khula-kudi (h), Brahmi, Karringa (bom), Vallarai (dec), Von-deloga (k).

Til (b), Sesamum indicum (bot), Mithai til, Krishna-til (h), Wal-lenney, Yelloocheddi (t), Manchinune nuvulu (te), Barik til (dec).

Tobacco (e), Nicotiana tabacum (bot), Tamaku (h), Tamak (b), Tamrakuta (s), Tamaku (dec), Pugai-ilai (t), Poglku, Dhurmarapatramu (te), Higoseppu (k), Tamakan, tombakhu (bom).

Tomato (e), Lycopersicum esculentum (bot), Belati Begoon (b,h).

Toolsy (b), Ocimum Sanctum (bot), The Sacred Basil (e), Kala-tulsi, Tulsi-baranda (h), Tulasi (bom), Tulasa (m), Talasi (g), Tulasi, Alangai, Pirundam (t), Tulashi, Krishna Tulasi, Gaggera-chettu (te), Tulasi gida (k).

Toona (b), Cedrela Toona (bot), Tooni, Nandibrikha (s), Lun, Mahanim, Mabalimbo, Tunkajhar (h), Deodari. Kuruk (m), Tunu-maram, Mali, Wunjuli (t), Nandichettu, Nandi (te), Kempu-gandagheri, Tunda, Devdari (k).

Toont (b), Morus indica (bot), Tut, Tutri, Toontrishaul (h), Kambali-buchi, Cambalichettu (te), Kambili-puch, Musokottayacheri (t), Mulberry (e), Tutri, Ambor, Setur, Tula ambor (bom), Tul (m), Shetur (g), Hippal-verali (k).

Topchini (b), Smilax Chinensis (bot), Shukchini (h), Pirangi-chekka (te), Paringay (t).

Torenia (bot), Torenia asiatica (?), Kapuka (in Southern India).

Torulata (b), Quamoclit Pinnata (bot), Kam lata (h).

Trisir-Mansa (b), Euphorbia Antiquorum (bot), Bajbaran, Tridhar-shend (h), Vajrakantaka (s), Narasija (m), Tandharishend

(g), Shadburuk-kalli, Tiri-kalli (t), Bomma Jemuda Bonta Chemuda (te), Mudu, Mula-Jemuda (k).

Ulat Chandal (b).—See Glory-lily

Vanda—See Rasna.
Vallisneria, Vallisneria spiralis (bot), Jhanji, Syala (h).

Water Chestnut (e)—See Paniphal.
Water-hyacinth (e), Eichornia crassipes (bot).
Water lily—See Shalook.
Water Melon (e), Citrullus Vulgaris (bot), Turbuj (h), Tarmuj (b), Tarbuz, Kalingad, Kalingam (bom), Pitcha Pullam (t).
Wheat (e), Triticum vulgare (bot).
Wood-apple—See Kath-Bæl.

Zinnia—Zinnia Elegans (bot), a common garden annual.

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